

EFFECT OF THROMBECTOMY AND OPERATIVE
TEMPORARY ARTERIOVENOUS SHUNT ON
ACUTE ILIOFEMORAL THROMBOSIS
A Radiologic Investigation

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Lund 1984

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Revision of the language was made by Dr Curt G Carlbom

This thesis is based on the following papers:

- I. ALBRECHTSSON U., EINARSSON E., EKLÖF B. and TYLÉN U.:
Thrombectomy and temporary arteriovenous shunt in ileofemoral thrombosis: An arteriographic evaluation of shunt function.
Acc for publ in Cardiovasc Intervent Radiol
- II. ALBRECHTSSON U., EINARSSON E., EKLÖF B. and TYLÉN U.:
Influence of temporary femoral arteriovenous shunt on blood pressure and flow.
Submitted for publ in Cardiovasc Intervent Radiol
- III. ALBRECHTSSON U., EINARSSON E. and EKLÖF B.: Femoral vein pressure measurements for evaluation of venous function in patients with postthrombotic iliac veins.
Cardiovasc Intervent Radiol 4 (1981), 43 - 50
- IV. ALBRECHTSSON U., EINARSSON E., EKLÖF B. and TYLÉN U.:
Thrombectomy and temporary arteriovenous shunt in acute deep ileofemoral venous thrombosis: Late phlebographic evaluation of iliac and common femoral veins.
Acc for publ in Cardiovasc Intervent Radiol

Reference to these papers will be made by the roman numerals I - IV.

Contents

	Page
Introduction	7
Material and methods	7
Chest examination	9
Arteriography	9
Pressure measurements in patients with patent shunt	9
Blood flow measurements	9
Phlebography	10
Femoral vein pressure measurement	10
Results	11
Chest examination	11
Arteriography	11
Pressure measurement	12
Blood flow measurements	12
Ascending phlebography	13
Femoral vein pressure measurements and pelvic phlebography	13
Follow-up phlebography	13
Venous pressure measurement	14
Discussion	14
Complications	18
Summary	20
References	21

- I. Thrombectomy and temporary arteriovenous shunt in ileofemoral thrombosis: an arteriographic evaluation of shunt function

- II. Influence of temporary femoral arteriovenous shunt in blood pressure and flow

- III. Femoral vein pressure measurements for evaluation of venous function in patients with postthrombotic iliac veins

- IV. Thrombectomy and temporary arteriovenous shunt in acute deep ileofemoral thrombosis: late phlebographic evaluation of iliac and common femoral veins.

Deep venous thrombosis is a common disease and the resulting post-thrombotic symptoms are often troublesome and sometimes crippling, especially for patients with ileofemoral thrombosis. The common method of treatment of acute venous thrombosis is anticoagulant or thrombolytic therapy /1, 7, 18, 34, 36/. However, thrombolytic therapy is contraindicated in many patients and is probably not as effective as previously thought. Thrombectomy for acute ileofemoral thrombosis became extensively used during the 1960s after encouraging reports. The Fogarty's balloon catheter technique made the operations easier and the results improved when compared with previous treatment. Numerous reports appeared on the subject. Based on some 900 patients, the overall clinical result was considered good in about 80 per cent /3, 10, 11, 14, 15, 22, 29, 33, 39/. Recurrent thrombosis, however, was found to be common and the clinical improvement did not correspond to the phlebographic findings at follow-up /3, 11, 22, 24/. Poor long-term results after thrombectomy was stressed in a follow-up study.

It is generally agreed that the most severe cases of post-thrombotic disease are those with changes in the common femoral and iliac veins, probably because venous collaterals in the groin cannot develop to the same extent as in the leg and pelvis /3, 42, 43/. Few studies have been presented where thrombectomy has been used in combination with temporary arteriovenous shunts. The results were in two of these studies improved compared with only thrombectomy. In an effort to improve the treatment of ileofemoral thrombosis, we have used thrombectomy combined with a temporary arteriovenous shunt in 70 patients. The aims of the present study were

- 1/ to obtain an objective morphological and physiological description of the changes caused by a functioning arteriovenous shunt as studied with arteriography, blood pressure and flow measurements, and
- 2/ to find an objective method of evaluating the ileofemoral segment after treatment of ileofemoral thrombosis by performing a thrombectomy and constructing an arteriovenous shunt.

Material and methods

The clinical investigation includes 70 patients who underwent a thrombectomy and had a temporary constructed arteriovenous shunt (Table I). Indication for an operation was a thrombosis extending above the inguinal ligament. In 19 patients the thrombosis reached the inferior vena cava. The clinically estimated age of the pelvic thrombosis at operation was 1 - 11 days (mean 3 days). Thrombectomy was performed with a Fogarty's balloon catheter proximally and distally from an incision in the femoral vein. The great saphenous vein or, in a few patients, one of its branches was after division anastomosed with the superficial femoral artery, thus creating an arteriovenous shunt.

An additional 40 patients treated for a high thrombosis with anticoagulant or thrombolytic therapy were included in a part of the study. Of these, 17 had a thrombosis restricted to the leg and 23 a thrombosis engaging pelvic veins (III).

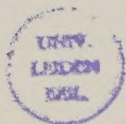


Table 1. Patients and examinations

Patients operated on	70 ^x
I. Arteriography	59 ^x
II. Blood flow measurement	16
Arterial pressure measurement	24
Venous pressure measurement	27
III. Femoral vein pressure measurement in non-operated patients	40
IV. Follow-up phlebography	52 ^x
Femoral vein pressure measurement	27 ^x

x/ One patient operated on both sides

Chest examination. In all our patients a radiographic examination of the chest was performed before shunt construction and on several occasions after (II).

Arteriography. (I) Postoperative arteriography was performed to evaluate morphological changes and shunt function. The examination was performed 8 - 135 days (mean 56 days) after the initial operation and prior to shunt closure. Fifty-nine patients, 35 males and 24 females, aged 14 - 84 years (mean 51 years) were examined. Twenty-four shunts were on the right, 34 on the left side, and one patient had bilateral shunts. Catheterization was performed from the contralateral femoral artery in all patients except in the one with bilateral shunts, in whom the examination was made from the left axillary artery. The catheter was placed selectively in the common femoral artery or in the external iliac artery. A thin-walled catheter with an end-hole and two side-holes (OD/ID 2.2/1.5 mm) was used in all the patients for angiography and for pressure and flow measurements. Contrast medium was injected with a pressure injector at a rate of 15 - 20 ml/s. For each injection 20 - 30 ml of contrast medium was used. Angiographic documentation was obtained with a serial film changer with a rate of 2 - 4 films/s over the groin and lower abdomen.

In 16 patients, arteriography of the contralateral normal side was done for a comparison. One patient was examined twice on the operated side.

Pressure measurements in patients with a patent shunt (II). Arterial blood pressure was measured in 24 patients from a level of about 20 cm distal to the shunt, at shunt level, and above the shunt level in the common femoral, external and common iliac arteries, and in the aorta. In most of the patients, the blood pressure was also measured in the contralateral iliac artery. Venous pressure was measured in 27 patients at the same levels as in the artery, but distal to the shunt level in only 8 patients. In 3 patients with a caval clip, the pressure was also measured above and below the clip.

All catheterizations were performed from the contralateral side except in one patient with a venous occlusion, in whom the pressure was measured after direct puncture of the vein. Thus, the catheter tip was placed in the flow direction during arterial pressure measurements distal to the aorta and against the direction of flow during venous pressure measurements distal to the inferior vena cava. Pressures were measured with a transducer (ENT 34, Elema-Schönander, Elema, Sweden) adjusted to a reference level 5 cm below the sternum with the patient supine.

Blood flow measurements, (II). Iliac blood flow was measured in 16 patients. The external iliac or common femoral artery and vein were catheterized from the contralateral side. The catheter tips were placed 5 - 15 cm proximal to the shunt, but distal to the internal iliac artery and vein. Blood flow was determined by injection of a bolus of 1 - 2 ml indocyanine green solution (Cardio-Green, Hynson, Westcott & Dunning Inc., USA). The dye concentration was measured by passing venous blood continuously at a rate of 0.5 ml/s through a spectrophotometer cuvette (Oxi-densitometer 351, Nycotron, Oslo, Norway). The electrical signal from the spectrophotometer was recorded with a single channel recorder (Electronic 194, Honeywell, England). Before measurement the catheters were thoroughly rinsed with the dye dilution. In all 16 patients, iliac artery flow and cardiac output were measured at rest. At the latter measurement the catheters were placed in the aorta and inferior vena cava, respectively. In 7 of the patients, additional measurements were performed after arresting blood flow to the leg with a blood pressure cuff at a pressure of 250 mm Hg.

The recirculation started before the dye concentration curve reached the baseline. The curve therefore was semilogarithmically extrapolated to the baseline. Integration of the area under the curve was made by tracing it on hard paper, which was cut out and weighed. Calibration was made after the measurements by mixing 0.05 and 0.1 ml of dye solution with 10 ml venous blood. The flow was calculated with a modified Stewart-Hamilton formula /13, 31/.

Cardiac output was measured in the same way with the exception that dye was injected into the inferior vena cava. For cardiac output measurements, usually 5 ml of dye solution was used.

In all patients 2 - 3 flow determinations were made for each measurement and the mean value was used.

Phlebography. Ascending phlebography was performed with the patient semierect. Contrast medium was injected in a superficial dorsal foot vein and roentgenograms were taken with an overhead tube in ante-posterior, oblique, and lateral projections of the calf and thigh. In 15 patients with functioning shunts, phlebography was performed early postoperatively to evaluate the results of thrombectomy (I).

Phlebography was performed in 52 (53 operated legs) of the 70 operated patients as a part of the follow-up examinations. Thirty males and 22 females, aged 14 - 72 years (mean 52 years), were examined 1 - 59 months (mean 15 months) after thrombectomy (IV).

Femoral and pelvic vein phlebography was performed after catheterization of both femoral veins with a 10-cm end-hole catheter adjusted for free flow. Phlebography was performed separately on both sides with the patient in a semierect position and with injection of 30 ml of contrast medium to evaluate the iliac veins. The femoral vein valve function was evaluated after injection of the same amount of contrast medium during a Valsalva manoeuvre (III, IV).

Femoral vein pressure measurement. The intravascular pressure was measured with a transducer adjusted to a reference level 5 cm below the sternum with the patient in the supine position. The transducer was calibrated with a vertically adjustable bottle with saline adjusted to 50 cm H₂O (37 mm Hg). The pressure was recorded in the supine patient at rest, during exercise (consisting of 20 powerful contractions of the calf muscle), and immediately after exercise. The recordings were repeated 2 - 3 times on both sides with continuous recording of the pressure on a polygraph.

Forty patients with post-thrombotic disease and 10 patients who underwent a thrombectomy were studied initially to evaluate the femoral vein pressure measurement as a method (III). During the follow-up studies, another 17 patients who had a thrombectomy and a temporary constructed arteriovenous shunt were examined with a femoral vein phlebography and pressure measurements. Totally, 27 patients of the 52 examined with ascending phlebography had femoral vein pressure measurements (IV). Femoral vein phlebography and pressure measurements were not performed in 25 of the patients, who at ascending phlebography had either normal pelvic veins or who had no appropriate vein that could be catheterized because of occlusion or pronounced scarring in the operated groin.

Results

Chest examination. In most of the patients the pre-operative chest radiographs were supine ones and were not appropriate for comparison with post-operative radiographs. In two patients with a flow of 1.4 and 2.2 litres/min, respectively, no change of heart or pulmonary vessels size was demonstrated. In 22 patients there was cardiac enlargement which, however, did not exceed the normal limits. Distension of the pulmonary vessels as a sign of increased cardiac output was also demonstrated in these patients, but no patient had any signs of cardiac incompensation.

Arteriography (I). A slight arterial stenosis was demonstrated in 12 and a pronounced stenotic narrowing in 2 of the 60 examined legs. The remaining 46 legs had no stenotic changes. All the changes were at the site of the anastomosis and were deemed as being caused by the surgical procedure. No arterial aneurysm or occlusion was found.

The diameter of the superficial femoral artery in 9 patients with occluded shunts was the same proximal and distal to the shunt level. In 51 legs with patent shunts, the mean increase in diameter of the superficial femoral artery proximal to the shunt was 2.1 mm (0 - 4 mm) when compared with the diameter of the artery distal to the shunt level. In the patient examined twice, 9 and 135 days after operation, the diameter of the superficial femoral artery proximal to the shunt increased from 10 to 13 mm and distal to the shunt from 7 to 9 mm between the two examinations. This means an increase in area of about 70 per cent.

In 16 patients, also examined on the normal side, the diameter of the superficial femoral artery on the operated side exceeded, on an average, that on the normal side by 2.5 mm (range 1 - 5 mm). Distal to the shunt, the difference was 0.4 mm (range 0 - 3 mm).

A patent shunt was found in 51 of the 60 examined legs (I, Table 1). The shunt length was between 20 and 75 mm (mean 40 mm) and the minimum diameter was between 2 and 9 mm (mean 5 mm). In 5 shunts an aneurysm was found with a diameter of 5 - 25 mm, the largest being in a branch of the great saphenous vein. In 3 of the shunts a localized stenosis of moderate degree was found, but it was impossible in most of the patients to exclude changes within the anastomosis because the shunt formed a more or less tortuous arch. Shunt diameter corresponded to 25 - 115 per cent (mean 50 %) of the diameter of its feeding artery.

In all the 51 legs with patent shunts at arteriography, there was good delineation of the drainage veins. Veins with normal diameters were demonstrated in 19 legs, a localized stenosis in 26, and occlusion in 6 - all changes proximal to the shunt level. The stenoses were situated in the common femoral vein in 17 and in the external or common iliac veins in 9 legs. The occlusions were in the common femoral vein in one and in the common iliac vein in 5 patients. A 5-cm-long aneurysm in an ascending lumbar vein was demonstrated in one patient with occlusion of the common iliac vein. This aneurysm probably resulted from an incorrectly performed thrombectomy. In 22 of the 25 patients with moderate and severe venous stenosis or occlusion, collateral flow in the groin or contrast flow in the distal direction from the shunt was seen. This was regarded as a sign of insufficient venous drainage in this situation with increased venous flow. In 2

patients, one normal and one with a stenosis, collateral flow was seen from a branch of the great saphenous vein. The remaining patients with normal veins or slight stenosis had no collateral flow.

Pressure measurement (II). Arterial pressure was measured in 24 patients, 19 with normal arteries and 5 with a stenosis. A systolic pressure gradient of 25 and 95 mm Hg, respectively, was found in 2 patients with severe stenosis (II: Table 1). In 3 patients with no stenosis observed at angiography, there was a systolic pressure gradient of up to 30 mm Hg at the shunt level. The remaining patients had the same pressure distal and proximal to the shunt. No differences in pressure were found between the femoral artery above the shunt level and the aorta.

A venous pressure measurement was performed in 26 patients from the contralateral side and in one patient with venous occlusion after direct puncture distal to the occlusion. No pressure gradient or a gradient of less than 5 mm Hg between the shunt level and inferior vena cava was found in all 9 patients with normal pelvic veins and in 5 with a stenosis. The remaining 12 patients with a stenosis of varying degree had a venous pressure gradient of 5 - 110 mm Hg. The patient with a venous occlusion had a gradient of 20 mm Hg between the femoral vein at the shunt level and the inferior vena cava.

Three patients with caval clips had a pressure gradient over the clips of 4 - 7 mm Hg.

Blood flow measurements (II). Blood flow was measured in the external iliac or common femoral artery and was found to be between 0.8 and 5.6 litres/min (mean 2.2 litres/min, II: Table 2). This measurement included flow through the shunt as well as to the leg. In an effort to measure shunt flow, the peripheral circulation was arrested with a blood pressure cuff, at a pressure of 250 mm Hg, high up on the thigh in 7 of the 16 examined patients. Arteriography performed using a blood pressure cuff demonstrated no change in arterial diameter and no flow in peripheral arteries with the exception of the circumflex collum femoral artery. No change in arterial blood pressure was seen after application of the blood pressure cuff. The flow measured in these 7 patients without a blood pressure cuff was 1.5 - 5.6 litres/min (mean 2.6 litres/min) and with the blood pressure cuff 1.3 - 4.9 litres/min (mean 2.5 litres/min), indicating that shunt flow constituted the main part of the iliac artery blood flow.

Cardiac output was 3.5 - 12.8 litres/min (mean 6.9 litres/min). Iliac artery flow thus corresponded to between 15 and 50 per cent of cardiac output. The correlation between iliac artery flow and cardiac output was good (II: Fig. 2).

The patients with a shunt diameter measuring 3 - 4 mm had an iliac artery flow of 1.1 - 2.2 litres/min, with a mean of 1.5 litres/min. Five of these 7 patients had normal veins, one a stenosis, and one an occlusion. A shunt diameter of 5 - 6 mm was found in 8 patients of whom one had normal veins and 7 a stenosis. Flow in these patients was 0.8 - 4.4 litres/min with a mean of 2.5 litres/min. One patient with a shunt diameter of 9 mm and a moderate stenosis had an iliac vein flow of 5.6 litres/min. Thus, the flow was higher with larger shunts and stenoses were more common in patients with larger shunts. The correlation, however, between shunt diameter and flow was poor.

Ascending phlebography. In 15 patients with a patent shunt the iliac veins were not seen in 8 and were poorly demonstrated in 7 patients at ascending phlebography (I). The reason for this was a marked contrast medium dilution above the shunt. Follow-up phlebography demonstrated post-thrombotic changes in calf and thigh veins in 48 legs, whereas 5 patients with only pelvic thrombosis had normal distal veins (IV).

Femoral vein pressure measurements and pelvic phlebography (III). Of the 50 first-examined patients, 40 had post-thrombotic disease of varying degree and in 10 patients a thrombectomy was performed and a temporary arteriovenous shunt constructed (III). Seventeen patients had normal iliac veins, 27 unilateral and 6 bilateral, or caval post-thrombotic disease. Eight patients had slight post-thrombotic changes; one had more pronounced changes with recanalization and collateral circulation; and 10 had an occlusion of the external and/or common iliac vein. Pressure changes in the individual leg during rest and exercise and the differences between the two legs were evaluated (III, Tables 1 and 2). In patients with normal pelvic veins, there was only a slight pressure elevation during exercise, and after exercise the pressure fell immediately to a pre-exercise level. There was no significant difference between the two sides. Of the 27 post-thrombotic patients, the pressure did not differ significantly from those with normal veins in 12, whereas 15 patients had a significant pressure elevation at rest, during exercise, and after exercise on the diseased side. After exercise the pressure did not return to the pre-exercise level for more than 40 s and there was a successive pressure elevation in each subsequent exercise period. The parameters with the greatest difference from normal were a pressure rise and a pressure difference between the two legs after exercise, whereas these two parameters during exercise showed less difference from normal.

The correlation with phlebography was poor. In the 12 post-thrombotic patients with normal pressures, 7 had moderate post-thrombotic changes and 3 severe changes. Two patients had occlusion of iliac veins but well-developed collaterals. In the 15 patients with pathological pressures, 8 patients had an occlusion of the iliac vein and 6 patients had severe post-thrombotic changes.

Follow-up phlebography (IV). Normal iliac veins were found in 20 legs, stenosis in 12, and an occlusion in 21. Three patients with a slight stenosis, 2 with a moderate stenosis, and one with a severe stenosis at arteriography had at the follow-up examination normal femoral and iliac veins, and in 3 patients there was an actual increase of venous diameter between the two examinations (IV, Table 1). In the other 3 patients the venous stenosis at arteriography was relative: depending on dilatation of the vein distal and proximal to the inguinal canal. One patient with normal veins at follow-up phlebography had an occluded shunt at arteriography and the pelvic veins were thus not demonstrated.

In the 12 patients with stenosis at follow-up phlebography, the degree of stenosis was unchanged in 4, increased in 3, and decreased in 4 compared with arteriography. Also in 2 of these patients there was an actual increase of minimum venous diameter between the two examinations.

Occlusion of iliac veins was demonstrated at phlebography in 21 patients. Compared with findings at arteriography, venous occlusion had occurred in 3 pa-

tients with normal veins, in 3 with a slight or moderate stenosis, and in 3 with a severe stenosis. Seven patients had at arteriography an occluded shunt, and thus their pelvic veins were not demonstrated. Compared with arteriography there was an additional 9 occlusions in previously patent veins. Three of these patients had a known recurrent thrombosis. In all the patients the occlusion was in the segment of the vein involved by the initial thrombosis.

One patient had had a thrombosis during the third month of pregnancy, and the initial phlebography, performed only to verify the diagnosis, did not demonstrate the complete extension. No follow-up arteriography was performed in this patient. Follow-up phlebography demonstrated occlusion of the inferior vena cava and both iliac veins; we do not know whether her changes were due to recurrent thrombosis or insufficient thrombectomy.

No relationship was found between iliac vein patency and the time between thrombectomy and shunt closure, or the time between thrombectomy and follow-up phlebography. There was, however, a tendency for a somewhat higher venous patency rate in those patients with a shunt diameter of 4 mm or less, and similar results were found at arteriography, as well as at follow-up phlebography.

Venous pressure measurement (IV). Bilateral femoral vein pressure was measured in 28 operated legs. Normal pressures were found in 13 phlebographically normal legs, in 9 with stenosis, and in one patient with a venous occlusion. Pathological pressure measurements were found in one patient with a moderate stenosis and 5 with a venous occlusion (IV, Table I). Twenty-four patients were not examined with pressure measurements and 8 of these had normal phlebography and the remaining 16 patients had femoral vein changes that precluded catheterization.

Patent iliac veins were shown by phlebography in 32 patients (60 %), although 12 (23 %) had some degree of stenosis. The pressure measurement was normal in 23 of 28 examined patients. Provided that the venous pressure was normal in the 8 patients with phlebographically normal veins, the combination of phlebography and pressure measurements revealed normal venous function in 31 of the 53 examined legs (60 %) in this late follow-up study.

Discussion

Surgical arteriovenous shunts are widely used for various medical reasons. They do, however, cause medical problems. Most reports concerning problems with long-term shunts have been published about patients on chronic haemodialysis /6, 12, 30, 35/. Temporary arteriovenous shunts were used mainly to maintain the patency of venous grafts in experimental work /8, 9, 17, 21, 28, 40, 44/ and were employed by several vascular surgeons in isolated patients in an effort to improve patency rate after iliac vein thrombectomy or cross-over or by-pass operations /2, 3, 5, 8, 23, 42/. There are few reports on routine clinical use. BAUMANN/3/ reported on 20 patients, but he found no significant difference when compared with conventional thrombectomy. VAN DE BERG /42/, on the other hand, found significant clinical improvement in 15 patients when using an arteriovenous shunt as a complement to thrombectomy. VOLLMAR and HUTSCHENREITER /43/ re-

ported a material comprising 55 patients of whom 42 had a functioning arteriovenous fistula and found in these patients a patency rate of iliac veins of 83 per cent compared with 61 per cent in the patients without an arteriovenous shunt.

Experimental investigations have shown that arteriovenous shunts result in a high flow in the veins proximal to the shunt without elevation of venous pressure /25, 26, 32, 38/. A direct correlation was found between fistula size and blood flow in arteries proximal to the shunt, significant decrease in distal arterial flow was found with a shunt diameter exceeding half the diameter of the feeding artery /16, 25, 26, 32/. However, in most experimental work the measurements were performed within 30 minutes after shunt construction, which probably make the results not directly applicable to our patients. Follow-up studies up to 1 year after shunt construction demonstrated that there was a continuous increase of shunt flow and proximal and distal arterial flow with time and also an increase of arterial diameter /38/. Also distal arterial pressure, which in all early measurements was significantly decreased, returned to normal levels. A steady increase of distal venous flow with time was also found.

In that we have studied a clinical material, repeated follow-up examinations have not been possible to perform. The increased flow in the iliac and common femoral arteries is reflected by the increase in diameter of the superficial femoral artery proximal to the shunt. A marked difference in arterial diameter proximal and distal to the shunt was present in patients with an open shunt, whereas in patients with an occluded shunt there was no difference (1). The superficial femoral artery was wider on the operated side proximal to the shunt level. Thus, an increase in diameter of 10 - 100 per cent (mean 30 %), corresponding to an increase in cross-sectional area between 20 and 300 per cent, was recorded. The patient examined twice had an increase in diameter from 10 to 13 mm (70 %) over a 4-month period, which reflects the increase of flow with time. Experimental studies have shown that there is a proportional increase in shunt flow with increasing diameter of the shunt up to a shunt diameter double that of the feeding artery. In our investigation the diameter of the shunt was up to 115 per cent of the feeding artery, with a mean of 50 per cent. Thus, there should be a good correlation between shunt diameter and flow, which we, however, did not find. In most of the patients the shunt formed a more or less tortuous arch and short constrictions within the anastomosis were not possible to exclude, which could explain the lack of correlation /4, 27/. The influence of venous stenosis or occlusion on shunt flow has not been evaluated previously, and in our study most of the patients in which flow measurements were performed had a venous stenosis.

There was, however, a tendency to increased flow with increasing diameter of the shunt. VOLLMAR and HUTSCHENREITER recommended that shunt flow be restricted to 200 - 400 ml/min at operation. Because flow measurements were not obtained at operation, a direct comparison is difficult to make, but probably the recommended flow was exceeded in most of our patients. Also the technique used by VOLLMAR and HUTSCHENREITER is different, as they always used a branch of the great saphenous vein to construct the shunt, whereas in our patients the great saphenous vein was used in nearly all of them.

At the follow-up arteriography, 18 patients has normal iliac veins. A varying degree of stenosis and occlusion of the veins was found in the remaining 26 patients (1, Table 1). In at least one patient with an occluded iliac vein, a complete thrombectomy was not performed: and in a few other patients with wall-ad-

herent thrombi, it was not possible to perform a total thrombectomy. In a few patients angiography consequently demonstrated recanalized thrombi with wall-adherent remnants in the iliac veins. However, in most of the patients with a stenosis, it had a uniform appearance: often several centimeters long, circular, and smooth. The stenosis was a good distance from the operation site in the external or common iliac vein in 9 of the patients.

In experimental work the Venturi effect has been found at high shunt flow /16, 19, 20/, and the venous stenosis found at arteriography in most instances had the same appearance. In 3 patients with this type of stenosis, there was an actual increase of venous diameter after shunt closure. Two of these patients had a severe and one a slight venous stenosis at arteriography, and in one patient with severe stenosis the vein was actually normal at the follow-up arteriographic examination. Of the 26 venous stenoses found at arteriography, 21 had an appearance that could be in accordance with the Venturi effect. After shunt formation a Venturi effect, of course, will be reversible, but it probably can become permanent as a result of postoperative fibrosis. Also speaking in favour of the presence of the Venturi effect is the fact that the blood flow in those patients with a normal or a slightly stenotic vein was less than in patients with a moderate to severe stenosis. At follow-up examination with phlebography, there also seemed to be a higher frequency of occlusions and stenoses in the patients with large shunts than in patients with small shunts (IV, Fig. 6). Perhaps the considerable higher shunt flow in our patients compared with that described by VOLLMAR and HUTSCHENREITER could be one reason for a lower patency rate.

Due to the Pitot effect, an over- or underestimation of blood pressure can be seen when measuring with an end-hole catheter, especially when the flow is high. To diminish false measurements, the catheters used had two side-holes, as well as an end-hole. In our measurements equal pressure was found in the aorta and in both iliac arteries, which indicates that the Pitot effect is without importance in these measurements, as the catheter tip was positioned in the direction of flow on the operated side and against the flow direction in the aorta and on the non-operated side. We also found the same pressure in the femoral artery at the shunt level, and distal and proximal to the shunt in 19 of the patients. A decrease of 10 - 95 mm Hg of systolic pressure at the shunt level was demonstrated in 5 patients of whom 2 had a severe stenosis in the artery at this site (II). In the remaining 3 patients where the pressure gradient was low, no arterial wall changes were demonstrated at arteriography. It was, however, impossible to exclude minor changes at the operation site. They may cause a pressure gradient because of the high flow rate.

The pressure fall at the shunt level found in experimental investigations at the time of shunt construction thus had, to a great extent, been compensated for in these late examinations. Similar observations were also described in experimental works with a long follow-up period /38/.

In our patients with normal veins at arteriography, there were pressure gradients between the shunt level and the inferior vena cava of less than 5 mm, a finding which is supported by experimental studies where normal venous pressures were found when there was no stenosis /26, 32, 38/. In 17 of our patients with venous stenosis, 12 had a pressure gradient over the stenosis exceeding 5 mm Hg, and all of these patients also had collateral venous circulation. The most pronounced

changes were found in a patient with a severe stenosis and a gradient of 110 mm Hg. One patient with a venous occlusion proximal to the shunt had a shunt-level pressure of 25 mm Hg compared with 5 mm Hg in the inferior vena cava.

As in the group of patients in which arterial pressure measurements were performed, an error due to the Pitot effect could exist in the veins. In all our patients, pressure was measured on the operated side above the stenoses, in the inferior vena cava, and on the non-operated side; and no pressure difference between these veins was seen. Thus, we have found no evidence of any significant overestimation of venous pressure depending on the Pitot effect.

A negative pressure has in experimental studies been recorded in a stenosis caused by the Venturi effect /16, 19, 20/. In several of the stenoses that we observed during arteriography, this could be the cause, but a negative pressure was not recorded in any of the patients. However, those patients in which the stenosis disappeared after shunt closure were not examined with pressure measurements. In the other patients the stenoses could already have become permanent by fibrotic scarring at the time of pressure measurement, and at the time of examination we were not fully aware of the possibility of the Venturi effect and thus we did not make special efforts to record the pressure in different parts of the stenosis.

The method of blood flow calculation in these patients implies that there is an overestimation of shunt flow because dye to the legs is included in the calculation. In our patients shunt occlusion through external compression, as a rule, was not possible, which precluded separate measurement of leg flow. To circumvent this, all vessels distal to the shunt were occluded with a blood pressure cuff at a pressure of 250 mm Hg. As pressure measurement and arteriography did not show any change in proximal vessels compared with examination without a cuff, the flow values obtained with a blood pressure cuff can be regarded as shunt flow. The correlation between flow measured with and without a blood pressure cuff was good and almost the same, which is to be expected, as normal flow in the leg is 0.2 - 0.3 litres/min at rest. This low flow is well within the variations of the method considering the high flow rate. Thus, the flow measurements without a blood pressure cuff could be regarded as shunt flow. Cardiac output was increased in all patients and the correlation between shunt flow and cardiac output was good. After subtraction of shunt flow, cardiac output was 2.1 - 7.1 litres/min (mean 4.7 litres/min), which in all patients but one was within normal limits at rest. In the patient with cardiac output after subtraction of shunt flow of 2.1 litres/min, there was an occlusion of the iliac vein and flow was measured after direct puncture of the femoral vein at the shunt level. Dye for cardiac output measurement and venous sampling was injected in the femoral vein on the operated side, and there was considerable collateral and retrograde flow in the veins. This could explain a too high iliac flow or a too low cardiac output measurement.

The most important error with the dye dilution method is methodological. Indocyanine green is known to be bound to proteins adhering to the catheter wall, and this was therefore carefully rinsed with dye solution before measurement to saturate the protein film with dye /31/. In some patients there was an apparent loss of dye at the first measurement, and in these cases this curve was not included in the study. To secure complete mixing of dye with blood, the end-hole catheter also had two side-holes. Care was taken to place the tip well distal to

the internal iliac artery to avoid dye loss due to spill-back. Thus, there were no indications for an incorrect measurement owing to poor mixing, adherence to the catheter wall, or loss of dye due to spill-back, except in the one patient where dye was injected distal to the venous occlusion.

The most important source of overestimating flow with indocyanine green is said to be the shift of absorption spectra that takes place during the initial 6 s after injection /37/. This means that during the first few seconds only part of the indocyanine green in the cuvette is measured and there can be an overestimation of flow of up to 100 per cent. In our study the appearance time, e.g. the time between dye injection and arrival of the dye to the cuvette, was less than 4 s in 2 patients, between 4 to 6 s in 11, and more than 6 s in 3 patients. The degree of overestimation can be up to 40 per cent with an appearance time of less than 4 s and about 10 - 15 per cent with an appearance time of 4 - 6 s. Other authors, however, denied this delayed spectral shift and claimed it to be less than 2 s /41/. In our material no patient had such a short appearance time.

The cardiac output measurement was not impaired by the same possible error, as the appearance time was more than 10 s in all patients. The good correlation between iliac artery flow and cardiac output indicates that the overestimation of flow is low and that the error is about the same in all patients.

The blood flow measured in our series was high compared with those recorded experimentally and recommended by VOLLMAR and HUTSCHENREITER in temporary arteriovenous shunts. However, most of the measurements in the experimental studies and those made by VOLLMAR and HUTSCHENREITER were at the time of shunt construction, and it was shown that there was an increase of shunt flow up to 1 year after shunt construction. However, even with an increase of 100 per cent between shunt construction and flow measurement, the recommended values are greatly exceeded.

Complications

No complications that could be attributed to the arteriovenous shunt were seen in the patients studied. However, in one patient operated on later, a shunt had to be closed after 2 hours because of cardiac decompensation. In another patient who had an enlarged shunt and occlusion of external and common iliac veins, the well-developed collateral circulation made shunt closure impossible because of perfuse bleeding from the incision at operation. The shunt was closed with a balloon catheter from the contralateral side for 48 hours. During shunt closure, a thrombosis developed that occluded the shunt as well as the femoral vein (Fig. 1). The patient was, however, improved.

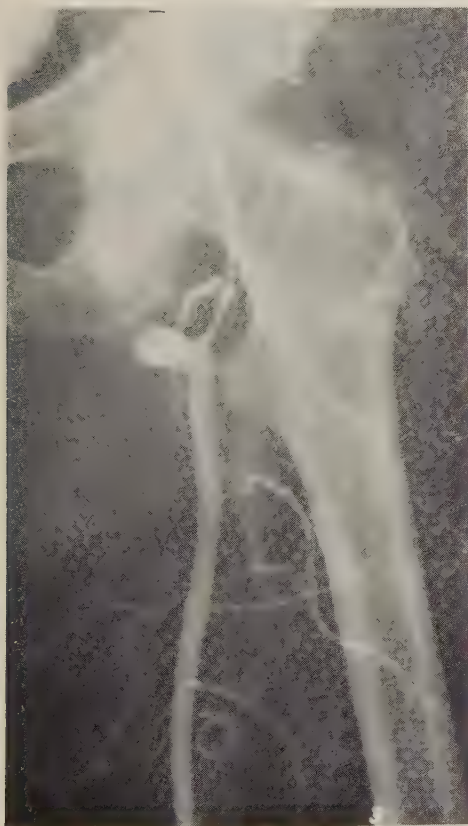
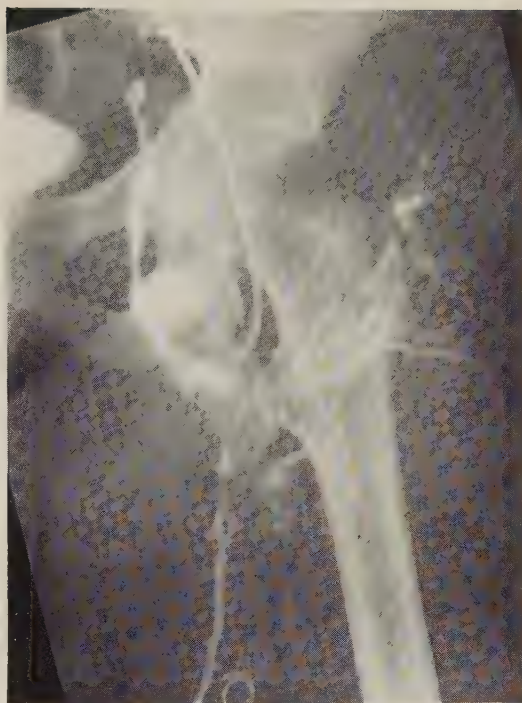
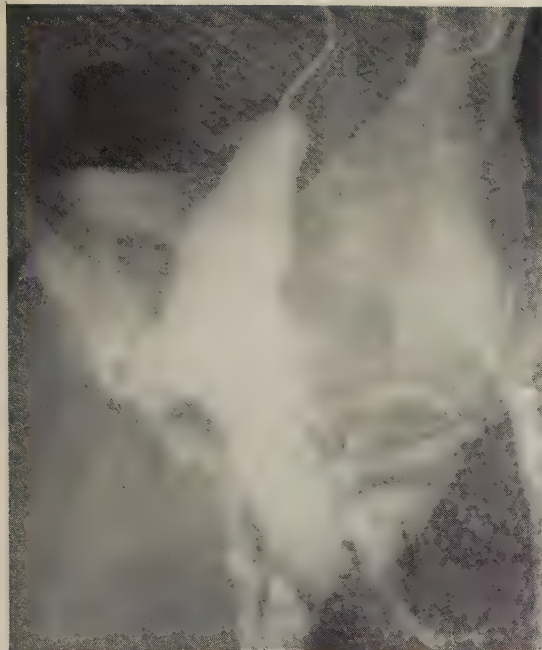


Fig. 1. 47-year old female with a shunt, impossible to close at operation because of profuse bleeding from the incision. A. Arteriography demonstrates the large shunt and dilated femoral veins occluded at the inguinal ligament. Well developed collateral circulation. B. Contrast injection through a balloon catheter placed in the shunt for 24 hours. Partial thrombosis of femoral vein. Note coil at the bottom of the film which was placed in the shunt but momentarily flushed into the femoral vein. C. Selective angiography of the femoral artery after 48 hours demonstrates the first part of the shunt where the balloon was placed. No contrast passage into the venous system.

Summary

With the introduction of the new treatment method, it is essential to have an objective evaluation of the results. In our study we made an effort to evaluate some of the morphological and physiological changes of an arteriovenous shunt between the superficial femoral artery and the common femoral vein.

The high flow created with arteriovenous shunts gave few symptoms from the systemic circulation and cardiac function. Circulation to the leg distal to the arteriovenous shunt is not compromised, and the arterial pressure proximal and distal to the arteriovenous shunt is not decreased. There was no elevation of venous pressure with the functioning shunt unless there was a concomitant stenosis. With the created high flow, there was probably a Venturi effect in the femoral and iliac veins that may contribute to the development of venous stenosis or occlusion. The shunt flow was higher with increasing shunt diameter, and venous stenosis or occlusion was more common with larger shunts. The results of the clinical study are that thrombectomy and a temporary arteriovenous shunt are as good as conventional methods in the treatment of ileofemoral thrombosis. It is probable that a reduction of shunt diameter and an increase of resistance in the shunt could be obtained by using a branch of the great saphenous vein as a shunt instead of the main vein as recommended by VOLLMAR and HUTSCHENREITER. This would diminish the shunt flow and perhaps significantly increase the success rate of the operation.

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THROMBECTOMY AND TEMPORARY ARTERIOVENOUS SHUNT
IN ILEOFEMORAL THROMBOSIS:
AN ARTERIOGRAPHIC EVALUATION OF SHUNT FUNCTION

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Abstract

Seventy patients with acute thrombosis of iliac veins underwent a thrombectomy and construction of a temporary arteriovenous shunt. Of 60 arteriographically examined shunts, 51 (85 %) were patent. In these 51 legs the veins proximal to the shunt were normal in 19 legs (37 %), slightly to moderately stenotic in 19 (37 %), severely stenotic in 7 (14 %), and occluded in 6 legs (12 %). These early results are promising and indicate probable favourable long-term results in about 75 per cent of such patients.

Key words

Ileofemoral thrombosis - Thrombectomy - Temporary arteriovenous shunt -
- Postoperative arteriography

The therapeutic objective in acute ileofemoral thrombosis is prevention of pulmonary embolism, venous gangrene, and post-thrombotic syndrome. Following acute venous thrombosis, the iliac veins tend to remain partially occluded, probably depending upon the degree of development of collateral channels. In patients with poor collateralization, this obstruction causes venous hypertension with secondary oedema and, in some patients, venous claudication. To date no method of treatment has been fully successful. Anticoagulant therapy can prevent further growth of the thrombus, but neither reopens occluded vessels nor does it necessarily prevent pulmonary embolism.

There have been promising reports of thrombolytic therapy with streptokinase or urokinase. Theoretically, this is an effective treatment, as it activates the fibrinolytic system; however, our results have been poor and severe complications, including rupture of the liver and spleen, have occurred /5/.

Thrombectomy was first described by SHEPELMANN in 1910, and it was used mainly during the 1960s. There are several reports of good results with this method, though mainly based on short-term follow-up clinical examination. In approximately 900 patients reported by different authors, the results have been good in 20 - 70 per cent (mean 50 %) of patients and poor in 6 - 37 per cent (mean 19 %) /6/.

Complications and poor results with thrombolytic therapy have forced us to abandon this method, and we now use thrombectomy and a temporary AV shunt as the standard treatment in acute ileofemoral thrombosis. This study is an arteriographic evaluation of early results in the first 70 patients.

Materials and methods

Since October 1974, 70 patients have undergone a thrombectomy and have had a temporary constructed arteriovenous shunt. The indications for operation were a thrombosis extending above the inguinal ligament in previously healthy patients and phlegmasia caerulea dolens. All patients had thrombosis of pelvic veins and in 19 also the inferior vena cava was involved. The clinically estimated age of the pelvic thromboses at operation was 1 - 11 days (mean 3 days). However, 11 of the patients

had had symptoms of a leg thrombosis not involving the pelvic veins for 11 days to 3 months.

Thrombectomy was performed with a Fogarty's balloon catheter proximally and distally from an incision in the femoral vein. The great saphenous vein, or in a few patients, one of its branches, was anastomosed after division end-to-side with the superficial femoral artery, thus creating an arteriovenous shunt. Postoperative arteriography was performed to evaluate the shunt function and the status of the venous system.

Thirty-five male and 24 female patients, aged 14 - 84 years (mean 51 years) were examined. Twenty-four shunts were on the right side, 34 on the left, and one patient had bilateral shunts. A total of 60 shunts were examined. Arteriography was not performed in 11 patients who were lost to follow-up because of allergy, pregnancy, sickness or death due to other diseases. Arteriography was performed 8 - 135 days (mean 56 days) after the initial operation and prior to shunt closure at a second operation. Catheterization was made from the contralateral femoral artery in all our patients but one: here it was performed from the left axillary artery. The catheter was placed selectively in the common femoral artery in most patients or in the external iliac artery and radiograms were taken over the groin and lower abdomen with a serial film changer. Contrast medium was injected with a pressure injector at a rate of 15 - 20 ml/s. For each injection 25 - 30 ml of contrast medium was used. In 16 patients arteriography of the contralateral normal side was performed for a comparison, and one patient was examined twice on the operated side. In another 15 patients with functioning shunts, ascending phlebography was performed to evaluate the results of early operative thrombectomy.

The roentgenographs were reviewed and the vascular changes were analysed and classified into 5 groups (normal, slight stenosis /< 75 % area reduction/, moderate stenosis /75 - 90 % area reduction/, severe stenosis /> 90 % area reduction/, and occlusion), depending on cross-sectional area reduction, which was estimated from the reduction in calibre of the affected vessel.

Results

Arteriography. A normal artery was found in 46 of 60 examined legs (Table 1). Slight irregularity or stenosis with an estimated cross-sectional area reduction of less than 75 per cent was demonstrated in 12 legs. Two had a more pronounced narrowing, with a stenosis of 75 - 90 per cent at the site of the anastomosis (Fig. 1). No arterial aneurysms were found. The diameter of the superficial femoral artery in the patients with patent shunts was 7 - 15 mm above and 6 - 14 mm below the shunts. The difference in arterial diameter above and below the shunt was 0 - 4 mm (mean 2.1 mm) in these patients, whereas in 9 patients with occluded shunts there was no difference.

Of 16 patients also examined on the normal side, the arterial diameter on the right and left side was the same in one patient with an occluded shunt, whereas in the other 15 patients the artery on the operated side was 1 - 5 mm (mean 2.5 mm) wider above and 0 - 3 mm (mean 0.4 mm) wider below the shunt than on the normal side (Fig. 2). In the patient examined twice, 9 and 135 days after operation, the arterial diameter increased from 10 to 13 mm above the shunt and from 7 to 9 mm below the shunt between the two examinations (Fig. 3).

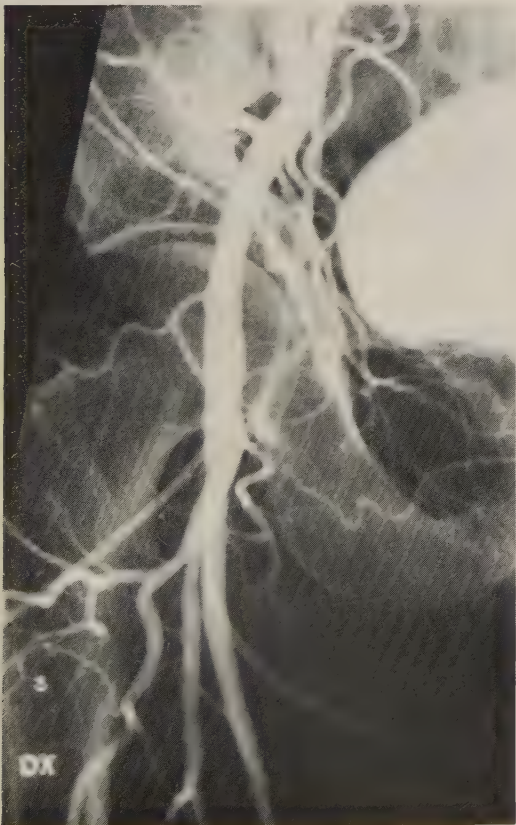
Table 1. Results at arteriography in the
60 examined legs.

Artery	(60)	Shunt	(60)	Iliac vein	(51)
Normal	46	Patent	51	Normal	19
Slight stenosis	12	Aneurysm	5	Stenosis	26
Severe stenosis	2	Stenosis	3	Occlusion	6
Occlusion	-	Occlusion	9	Aneurysm	1
Aneurysm	-				



Fig. 1. Female, aged 65 years. Moderate stenosis of the superficial femoral artery at the anastomosis and pronounced stenosis of the shunt. Iliac veins are normal.

Below: Fig. 2. Male aged 65 years. A. Normal arteriography on the right side. B. On the left side, a functioning shunt: marked increase of arterial diameter above the shunt and equal below compared with the normal right side.



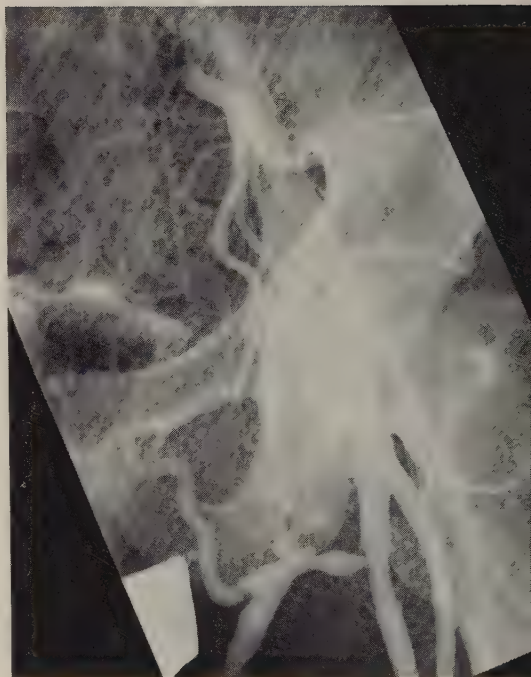
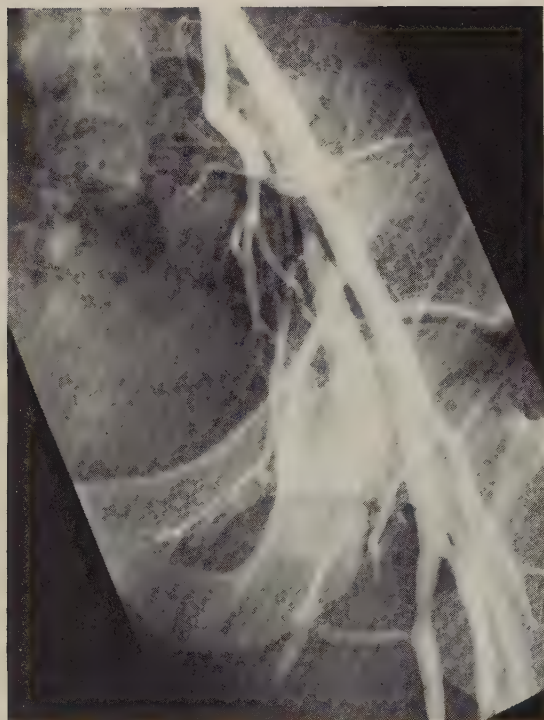


Fig. 3. Male aged 25 years. A. First examination 9 days after the thrombectomy: well functioning shunt created with a branch of the great saphenous vein. B. Second examination 4,5 months later: arterial diameter has increased; an aneurysm has developed in the shunt, which is stenosed as before; and collateral circulation from the great saphenous vein is demonstrated.

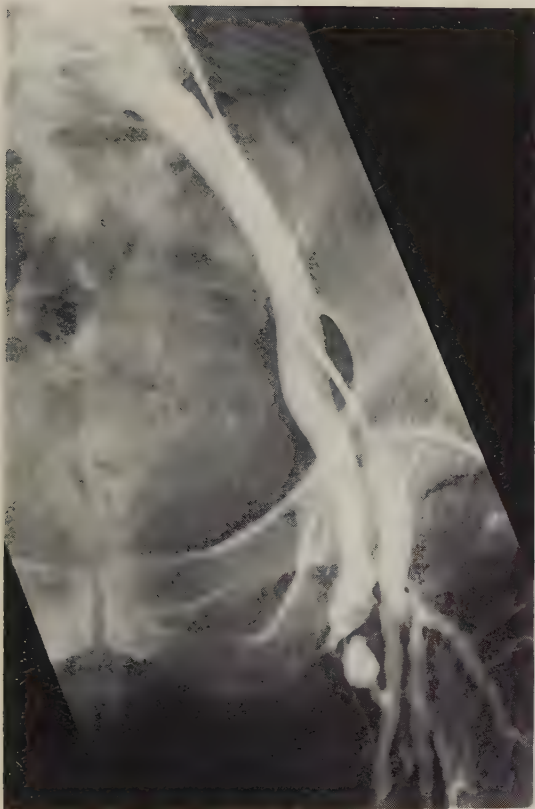


Fig. 4. Female aged 62 years. A. Arteriography shows a shunt aneurysm, but otherwise normal conditions. No contrast reflux into distal veins. B. Same examination; selective catheterization of deep femoral vein demonstrates the normal vein.

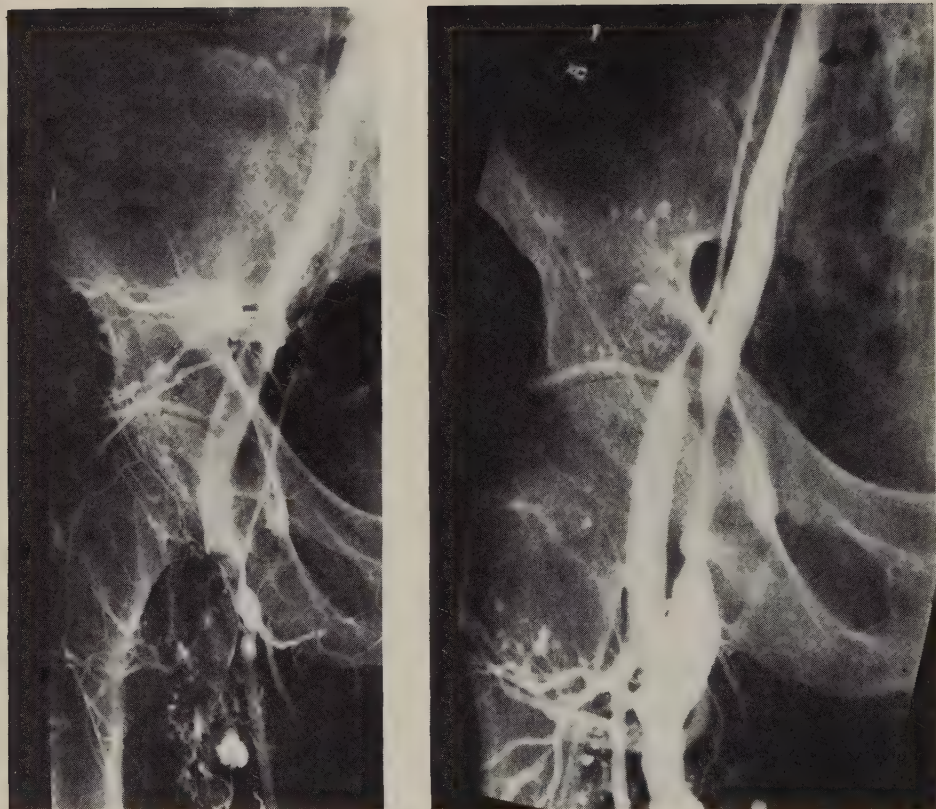


Fig. 5. Male aged 62 years. A. Initial thrombus. B. Arteriography shows a pronounced somewhat irregular stenosis, venous reflux, and collateral circulation.

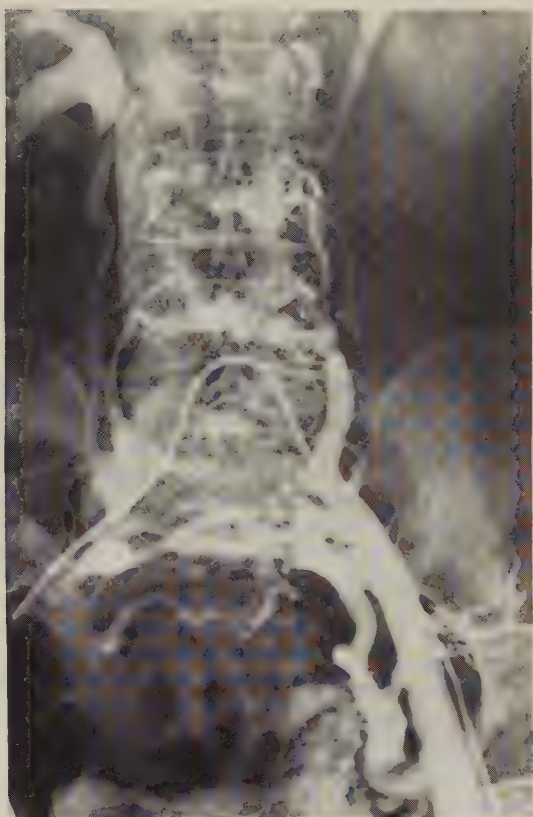
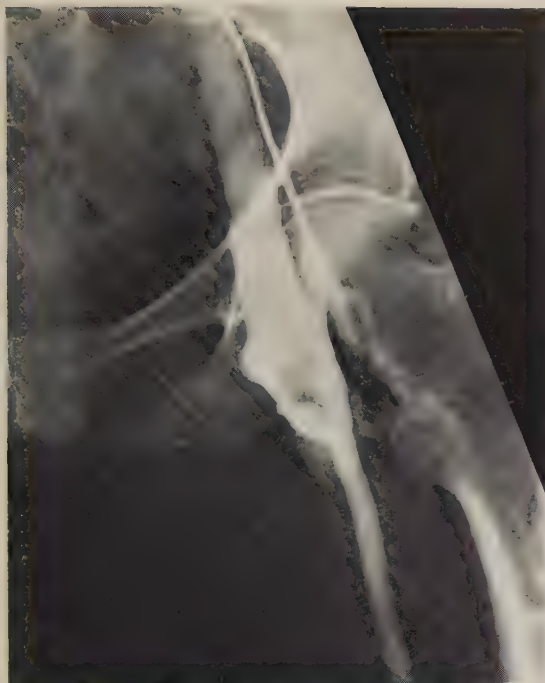


Fig. 6. Female aged 66 years.
A. Normal shunt function and
external iliac vein. B. Occlu-
sion of common iliac vein with
pronounced collateral circula-
tion.



Fig. 7. Female aged 73 years.
Occlusion of common iliac ar-
tery and aneurysm of a lumbar
ascending vein due to an un-
successful thrombectomy.



Fig. 8. Male aged 24 years. A. Ascending phlebography shows a normal superficial femoral vein. Because of contrast medium dilution, no veins are demonstrated above this level. B. Arteriography 3 days later shows normal iliac veins.

Shunt. Fifty-one of the 60 arteriovenous shunts were patent and of these 43 had no obstruction. The length of the shunts was 20 - 75 mm (mean 40 mm) and the minimum diameter 2 - 9 mm (mean 5 mm). In 5 of the shunts, an aneurysm was found with a diameter of 5 - 25 mm, the largest being in a branch of the great saphenous vein 2 cm from the shunt (Figs. 3 and 4). In 3 shunts a localized stenosis of moderate degree was found (Fig. 1), but it was impossible to exclude a short narrowing within the anastomosis in most of the patients because the shunt formed a more or less tortuous arch. The shunt diameter was 23 - 115 per cent (mean 50 %) of the diameter of its feeding artery. In only one patient did the shunt exceed the feeding artery in diameter.

Draining veins. In all 51 legs with patent shunts, there was good contrast delineation of the draining veins. The common femoral and iliac veins were normal in 19 legs (Figs. 1, 2, 4 and 5) whereas 26 had a localized stenosis (Fig. 5) and 6 an occlusion (Fig. 6). The stenosis was in the common femoral vein in 17 legs and in the external or common iliac vein, well away from the operation site in 9 legs. The area reduction was estimated to be less than 75 per cent (slight stenosis) in 7, 75 - 90 per cent (moderate stenosis) in 12, and more than 90 per cent (severe stenosis) in 7 legs. The occlusions were in the femoral vein (one patient), external iliac (2 patients), and common iliac vein (3 patients). In one patient with occlusion of the left common iliac vein and collateral flow to the ascending lumbar veins, there was in one vein an aneurysm with a diameter of 5 cm located 5 cm from the iliac vein (Fig. 7).

Venous collateral flow in the groin and pelvic veins was demonstrated in one patient without stenosis and in one patient with a slight stenosis; in both, blood flow was from a branch of the shunt (Fig. 3). In the 25 patients with moderate and severe iliac vein stenosis or venous occlusion, collateral flow was seen in 19.

Contrast flow from the shunt in a distal direction, more than 10 cm into the deep of superficial femoral vein, was only demonstrated in 12 of these 25 patients. Venous flow in a distal direction or collateral flow or both were seen in 22 of them. Of the 6 patients with venous occlusion, 4 had reflux.

Ascending phlebography. Ascending phlebography was used to evaluate the thrombectomy results in 15 patients - all with patent arteriovenous shunts. Free flow in the iliac vein was demonstrated in 7 patients, but in 5 of them there was very poor visualization of the iliac veins due to marked contrast medium dilution above the shunt (Fig. 8). Diversion of flow into collateral veins made evaluation of iliac veins impossible in 8 patients.

No difference in results was found at arteriography when the findings were related to the age of the thrombus. However, only 2 patients had a clinical history of iliac vein thrombosis of more than 7 days. Nor was there any differences between patients examined at different time intervals after operation.

Discussion

Surgical arteriovenous shunts are widely used in medical treatment. Most reports concern problems with long-term shunts in patients on chronic haemodialysis /16/. Temporary arteriovenous shunts have been used mainly to maintain the patency of venous grafts in experimental work and by several authors in isolated patients in an effort to improve patency rate after iliac vein thrombectomy or cross-over by-pass operation. But there are few reports on their routine clinical use /2, 10, 11, 14, 18, 20/. BAUMANN /1/ reported on 20 patients, but found no significant difference when compared with conventional thrombectomy. VAN DE BERG, on the other hand, reported a significant clinical improvement in 15 patients when using an arteriovenous shunt as a complement to thrombectomy /19/.

Experimental works have demonstrated that arteriovenous shunts produce high flow rates in the veins proximal to the shunt, as high pressure arterial blood is directed into the venous system /3, 4, 13/. Venous pressure is not elevated more than a few mm of Hg unless there is an attendant increase in proximal venous resistance /3, 4/, and venous pressure can be negative /8,9, 17/. A direct correlation has been found between fistula size and blood flow in arteries proximal to the shunt; a significant decrease in distal arterial blood flow has been found when the shunt diameter exceeds half the diameter of the proximal artery /7, 12/. Most of these experimental measurements, however, were performed 30 minutes after shunt construction, which probably means that the results are not directly applicable to our patients. It seems that the feeding artery adapts to the increased flow by increasing its diameter, as demonstrated in our study where a mean diameter increase of 32 per cent was found as compared with the normal side in the 15 patients examined bilaterally. The increase of arterial diameter distal to the shunt is probably also an adjustment to the decrease in distal pressure in order to maintain normal or, in some cases, increased flow /17/. None of the patients in this study had any additional symptoms of arterial insufficiency after shunt construction, not even the two patients with marked arterial stenosis. In no patient was reversal of distal artery flow demonstrated, which often has been described in side-to-side anastomoses /7/.

The increase of arterial diameter occurs early; in one patient examined 8 days after operation, there was an increase in diameter of 2 mm compared with the normal side. In the patient examined on two occasions, there also was a marked increase in arterial diameter between the two examinations 9 and 135 days after operation.

Shunt occlusion was present in 9 patients (15 %), which is a lower frequency than is normally found in haemodialysis shunts. However, in our patients there was a short follow-up time compared with examinations performed on haemodialysis shunts, which could explain the difference. The reason for shunt occlusion is not known, but a probable explanation is poor venous run-off.

The main purpose for surgical construction of the arteriovenous shunt is to maintain patency of the thrombectomized venous segment and to induce the development of sufficient collateral veins in cases of persistent occlusion or stenosis. The required duration of shunt patency for this to occur is not known, but the shunts found to be occluded at arteriography were considered clinically patent for 3 - 6 weeks after operation. It is not known if this is adequate time for establishing patency of the iliac vein, but in such cases shunt malfunction is a minor problem /3/.

Of the 51 legs examined on the venous side (patent arteriovenous shunts), 6 (12 %) had a venous occlusion which is about the same frequency as is seen in haemodialysis shunts. In at least one patient this was secondary to an insufficient initial thrombectomy. During thrombectomy the ascending lumbar vein instead of the inferior vena cava was catheterized, which is easily done, especially on the left side. The catheter balloon probably ruptured the ascending lumbar vein leading to the formation of a 5-cm-long aneurysm.

Proximal venous stenosis was seen in 26 of 51 legs. This type of lesion has been described as being due to reactive hyperplasia and fibrosis owing to elevated pressure /16/. Because there is experimental evidence that the venous pressure normally is not elevated, this is unlikely. In 17 of our patients the stenosis was below the inguinal ligament and could, of course, be a result of operative manipulation or scar formation in the soft tissue secondary to surgery. However, in 9 patients the stenosis was in the external or common iliac veins, a good distance from the operative site. The stenoses often had a similar appearance, with a several centimeter long stenotic segment tapering at both ends. The venous endothelium is very sensitive to trauma and a well-distended Fogarty's balloon can cause intimal avulsion and perhaps enough damage to effect development of stenosis. The microscopic changes could, in such cases, be secondary to an elevated pressure /16/.

Another possibility is that the high flow from the shunt into the vein causes the Venturi effect. Negative venous pressure proximal to an arteriovenous shunt has been recorded in experimental animals and models /8, 9, 17/. Further, venous collapse due to negative pressure has been found in experimental shunts /8/. During the postoperative healing process, fibrosis, then, can make this stenosis permanent. Because of the often pronounced oedema and tenderness at the operation site, external shunt occlusion by compression, to demonstrate reversibility of the stenosis, was not possible during arteriography in most patients, and hence a Venturi effect could not be excluded. Of the 26 stenoses, 21 had an appearance that could be attributed to a Venturi effect and, in such cases, was caused by a too rapid shunt flow.

Collateral circulation, including reflux in the distal direction from the draining veins was seen in many of our patients. This is a sign of insufficient venous drainage in this situation with increased venous flow. After shunt closure the venous stenosis in many patients will probably be of little or no significance. Absence of venous flow in a distal direction, on the other hand, does not indicate changes in the distal femoral veins (Fig. 4).

Ascending phlebography with a patent shunt to evaluate the thrombotized iliac veins must be regarded as an examination of minor usefulness, for it seldom yields relevant information. In most cases contrast medium dilution or diversion of blood flow from the lower leg to collaterals makes morphological evaluation of iliac veins impossible.

It is too early to evaluate the long-term results of this method. This early follow-up, however, shows promising results in that of the 51 legs examined with the shunt patent, only 6 (12 %) had a venous occlusion, which in at least one patient was due to an unsuccessful thrombectomy. In 7 legs with slight stenosis, the lumen was sufficient to permit the increased flow with a patent shunt and should after shunt closure still be sufficient. In many of the 12 legs with moderate venous stenosis, this will probably not be of such a degree to cause severe venous hyper-

tension. Of course, occlusion of the veins can occur after shunt closure and influence the results. A long-term follow-up study is in progress and these results will be used to determine further treatment in this patient group.

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II

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INFLUENCE OF TEMPORARY FEMORAL ARTERIOVENOUS SHUNT ON BLOOD PRESSURE AND FLOW

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Abstract

Thirty patients who underwent iliac or femoral thrombectomy and temporary arteriovenous shunt construction were examined with angiography, blood pressure, and blood flow measurements. Arterial pressure was the same in the aorta and superficial femoral artery (20 cm distal to the shunt) in patients without arterial stenosis. Venous pressure was normal at and distal to the shunt level in all patients without venous stenosis. In most patients with a venous stenosis, a pressure gradient over the stenosis was demonstrated. Shunt flow was 0.8 - 5.6 l/min (15 - 50 % of cardiac output). A good correlation existed between shunt flow and cardiac output. In most patients with a small shunt, shunt flow was low and the veins normal, whereas with larger shunts usually shunt flow and stenosis frequency was higher. Correlation between shunt diameter and flow was poor.

Key words

Temporary arteriovenous shunt - Blood flow - Blood pressure

Arteriovenous shunts have been commonly used in haemodialysis patients. Moreover, they are also used for administration of cytostatic drugs and for parenteral nutrition. The most common type of shunt is a side-to-side anastomosis between an artery and vein in the arm. The effect of this type of shunt on local and systemic haemodynamics has been thoroughly investigated /5, 6, 7, 8, 17/.

Temporary arteriovenous shunts after thrombectomy have been a routine method of treatment in acute deep ileofemoral venous thrombosis at our hospital since 1974. The arteriovenous shunt constructed in our patient group differs from the previously mentioned shunts in some important respects. Normally a loop-type shunt with side-to-end anastomosis between the superficial femoral artery and the great saphenous vein is made; and since the aim of the shunt is to increase flow in the iliac veins, it is, as a rule, localized in the upper thigh. Also the veins operated on are often damaged by the previous thrombosis and the subsequent thrombectomy.

We have evaluated the thrombectomy and shunt function by arteriography, blood pressure measurements, and flow determinations in 30 patients.

Materials and methods

Blood pressure and/or flow measurements were performed in 30 patients who had a thrombectomy and a temporary constructed arteriovenous shunt: in 14 only pressure measurements were made, in 3 only blood flow, and in 14 both. There were 21 males and 9 females, aged 18 to 84 years (mean 51 years). All the patients had a venous thrombosis extending above the inguinal ligament and had undergone thrombectomy proximally and distally from an incision in the common femoral vein. The arteriovenous shunt was made from the great saphenous vein which, after division, was anastomosed end-to-side with the superficial femoral artery.

Arteriography was performed to evaluate shunt function 1 to 19 weeks (mean 7.4 weeks) after thrombectomy and shunt formation. The femoral artery was catheterized from the contralateral side and pressures were recorded at approximately 20 cm distal to the shunt at the shunt level in the common femoral and iliac arteries and in the aorta in 24 patients. The venous side was catheterized in the same way and pressures were recorded at and above the shunt level in 27 patients and also about 20 cm below the shunt in 8. The catheters used were thin-walled angiography catheters, 80-cm long, with an end-hole and 2 side-holes within 0.5 cm from the tip (ID/OD 1.5/2.2 mm). The pressures were measured with a pressure transducer (ENT 34, Elema-Schönander, Elema, Sweden) adjusted to a reference level 5 cm below the sternum with the patient in the supine position. The catheter tip in the artery was directed with and in the vein against the direction of flow. Hence, due to the Pitot effect, the arterial pressures measured could be artificially somewhat lower and the venous pressure somewhat higher, but it is difficult to evaluate the degree of error. None of the pressure values given in Table 1 were, however, recorded in the narrowest parts of the vessels. The degree of stenosis was described as cross-sectional area reduction estimated from luminal diameter and classified as slight (< 75 %), moderate (75 - 90 %), and severe stenosis (>90%) /3, 13/.

Dye dilution measurements of peripheral blood flow were performed with the same catheters as the pressure measurements: arterial and venous catheters in the external iliac or common femoral artery and vein, respectively, with the tip 5 - 15 cm above the shunt. To avoid adherence of dye to the catheter wall, it was rinsed with dye before examination. The dye was injected manually, and to assure uniform mixing a catheter with an end-hole and two side-holes was used.

The flow was measured with the catheters in the external iliac or common femoral artery and vein in 16 patients at rest; in 7 patients all flow peripheral to the shunt was arrested with a blood pressure cuff at a pressure of 250 mm Hg and flow was measured before, with, and after deflation of the cuff. Cardiac output was measured in 16 patients with the catheters in the aorta and inferior vena cava by dye dilution.

Flow was determined by injection of a bolus of 1 - 2 ml indocyanine green solution (Cardio-green; Hynson, Westcott & Dunning Inc., USA) and venous blood was continuously sampled at a rate of 0.5 ml/s. The dye concentration was measured with a spectrophotometer and recorded on a potentiometer recorder. Calibration was made by mixing 0.05 and 0.1 ml of the dye solution with 10 ml of venous blood and permitting the mixture to pass through the spectrophotometer after the measurements. Because the recirculation started before the concentration curve reached the baseline, the curve was, after semilogarithmic plotting, extrapolated to the baseline (Fig. 1). The curve was integrated by tracing it on hard paper after which it was cut out and weighed. The flow was calculated with a modified Stewart-Hamilton formula. In all patients 2 - 3 flow determinations for each measurement were made and the mean value was used /6, 15, 18/.

The flow was calculated:

$$Q = \frac{100 \times q \times D \times M_1}{M} \text{ ml/s}$$

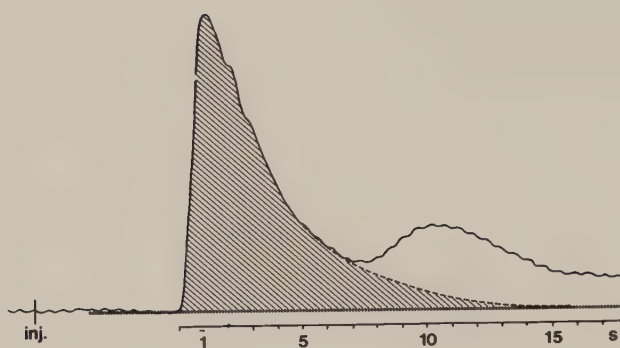


Fig. 1. Dye dilution curves from two different patients demonstrate shunt flow and recirculation. A (top) Patient No. 15; flow 5.6 l/min. B. (bottom) Patient No. 14; flow 2.3 l/min.

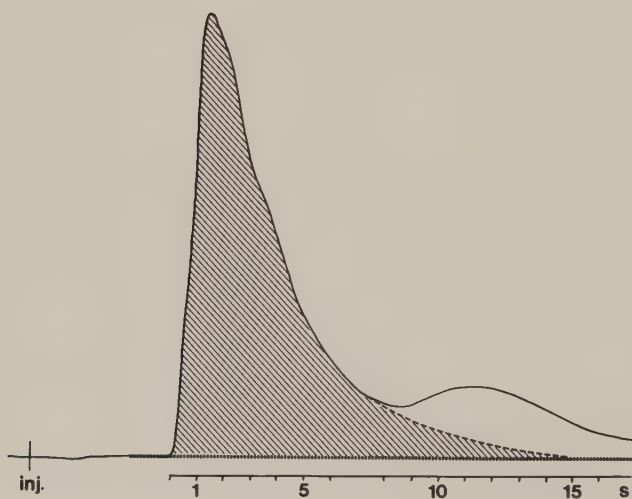


Table 1. Pressure measurements (mm Hg) in the individual patients and degree of stenosis (+ = slight; ++ = moderate; +++ = pronounced)

Pat. No.	Arterial pressure above shunt	Arterial pressure at/below shunt	Gradient	Stenosis (artery)	Venous pressure at/below shunt	Venous pressure above shunt/stenosis	Stenosis (vein)	Comment
1	145/80	115/60	30/20	-	11 - 13	11	-	---
2	125/60	130/60	-	+	5	5	-	---
3	125/65	125/65	-	-	11	10	1	Caval slip
4	120/60	120/60	-	-	19	19	-	Caval slip
5	225/100	130/75	95/25	+++	8	8	-	---
6	105/45	95/45	10/0	-	6	6	-	---
7	140/55	140/55	-	+	6	3	-	---
8	100/50	100/50	-	-	10	5	-	---
9	160/40	160/40	-	-	8	4	-	---
10	105/55	105/55	-	-	6 - 5	4	+	---
11	125/75	125/75	-	-	25	10	+	---
12	115/60	115/60	-	-	40	16	+	---
13					10	6	+	---
14					25	10	++	---
15	140/70	140/70	-	-	30	10	++	---
16	105/60	80/55 - 75/50	30/10	-	50	15	++	---
17	115/60	115/60	-	-	16	13	++	Caval slip
18	120/60	120/60	-	-	10	7	++	---
19	95/50	70/45	25/5	+++	25	8	++	---
20	120/80	120/80	-	-	10	5	++	---
21	110/50	110/50	-	++	6 - 4	4	+++	---
22					50	6	+++	---
23	160/120	160/120	-	-	120/60	10	+++	---
24	145/70	150/75	-	-	45 - 55	3	+++	---
25	100/60	100/60	-	-	25	5	+++	---
26	105/60	105/60	-	-	30	3	+++	---
27	130/60	130/60	-	-	25	5	Occlusion	---

where Q = blood flow; q = injected amount of dye (ml); D = deflection on the potentiometer recorded at calibration using an indicator dilution of 1/100; M = weight of the cut out curve; M_1 = weight of 1 square unit of the cut out curve.

When flow is calculated in this way, Q represents total flow in the common femoral or external iliac artery, and it was not possible to calculate shunt flow and the flow to the rest of the leg separately. Nor was it possible to occlude the shunt. To better evaluate the flow in the shunt, measurements were also performed with the peripheral circulation occluded with a blood pressure cuff in 7 patients. The iliac artery flow determined in this way corresponds to shunt flow.

Overestimation of flow due to changes in the absorption spectrum of indocyanine green may occur if the appearance time of the dye is less than 6 seconds, which was the case in all patients but 3 /18/. This overestimation can be considerable, especially when the appearance time is under 4 s, which, however, was the case in only 2 patients (Nos. 6 and 7). The degree of overestimation with an appearance time of 4 - 6 s is approximately 10 - 15 per cent.

In all patients an X-ray examination of the chest was made before shunt formation and on several occasions after. However, before operation the patient was, in many instances, examined supine and a comparison with the later examinations was difficult.

Results

Arterial pressure. Arterial pressure was measured in 24 patients. Equal pressure in the aorta, iliac and femoral artery at and below the shunt level was recorded in 19 of the patients. A decrease of systolic pressure at and below the shunt level of 10 - 95 mm Hg was demonstrated in the remaining 5 patients (Table 1). Two of these patients had a severe stenosis in the femoral artery at the shunt level, while the remaining 3 patients with a pressure gradient had no arterial stenosis. Another 3 patients with slight or moderate arterial stenosis had no pressure gradient. Reversal of arterial flow was not seen in any of the patients.

Venous pressure. Venous pressure was measured in 27 patients (Table 1). Normal veins were demonstrated at arteriography in 9 of them. A pressure elevation of less than 5 mm Hg in the femoral vein at the shunt level was detected in 3 of these patients when compared with the iliac vein - the pressure difference at the level of the inguinal ligament. In the remaining 6 patients, the pressure was the same in the femoral vein as in the iliac vein and the vena cava.

Various degrees of venous stenosis were demonstrated in 17 patients (all cranial to shunt level), and a venous occlusion was present in one. A systolic pressure gradient over the stenosis of 55 - 110 mm Hg was demonstrated in 2 of 6 patients with severe luminal narrowing. The remaining 15 patients with stenosis had a gradient of less than 44 mm Hg and 5 less than 5 mm Hg (Table 1). All the patients with a pressure gradient of more than 5 mm Hg had collateral venous circulation, as did 2 patients with a pressure gradient less than 5 mm Hg who had moderate and severe stenosis, respectively. The patient with a venous occlusion had a systolic pressure of 25 mm Hg at the shunt level distal to the occlusion measured by direct puncture and 5 mm Hg in the vena cava.

Table 2. Iliac artery flow measurements (l/min), cardiac output (l/min), and degree of venous stenosis in the individual patients. (+ = slight; ++ = moderate; +++ = pronounced)

Pat. No.	Age	Sex	Heart rate	Iliac artery flow A without cuff	Iliac artery flow B with cuff	hyper-aemia C	Cardiac output	Iliac artery flow as a percentage of cardiac output A	Iliac artery flow as a percentage of cardiac output B	Venous stenosis
2	68	M	56	1.4	1.4	2.1	5.6	25	25	-
5	68	F	79	1.8			8.3	21		-
6	58	M	75	2.2			6.9	32		-
7	70	M	71	3.4			9.4	36		-
8	57	M	64	1.1			4.6	25		-
12	32	M	60	4.0	3.7	3.8	8.0	50	46	+
14	18	M	97	2.3	2.7	5.9	8.3	28	32	++
15	54	M	102	5.6	4.9	5.5	12.8	49	38	++
16	26	F	112	0.8			5.2	15		++
17	36	M	114	4.4			11.1	40	40	++
18	50	M	71	2.2			6.1	35		++
20	22	M	64	0.9			3.9	22		++
22	27	F	79	1.3	1.3	1.9	4.9	27	27	+++
28	44	M	79	2.1	1.5	1.9	6.9	30	22	++
29	84	M	64	1.4	1.8	3.3	6.0	23	30	+
30	49	M	56	1.4			3.5	42		Occlusion

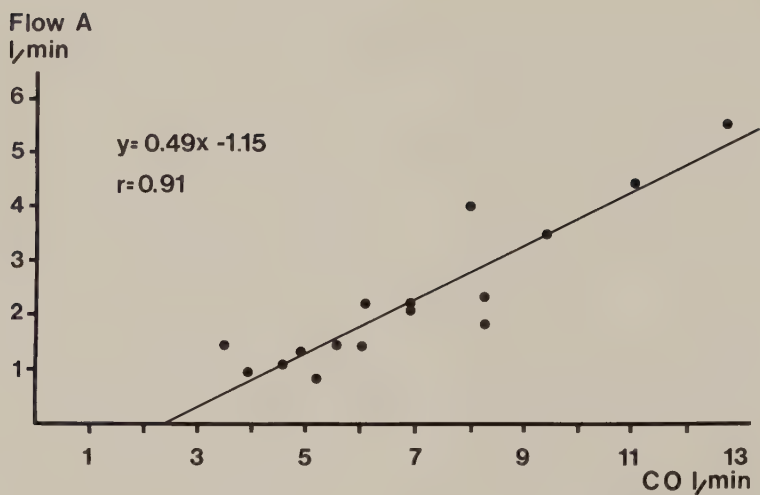


Fig. 2. Flow (l/min) at rest without a blood pressure cuff and cardiac output (CO, l/min) in 16 individual patients.

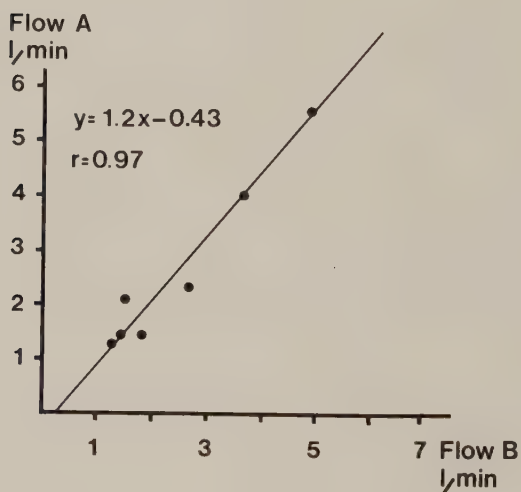


Fig. 3. Flow (l/min) in 7 patients at rest without (A) and with (B) a blood pressure cuff (250 mm Hg).

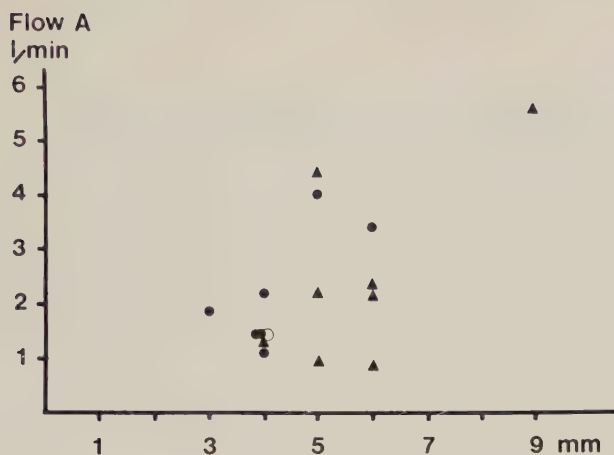


Fig. 4. Flow (l/min) without a blood pressure cuff compared with shunt diameter (mm).

- Normal iliac vein
- Iliac vein occluded
- ▲ Stenosis in iliac vein

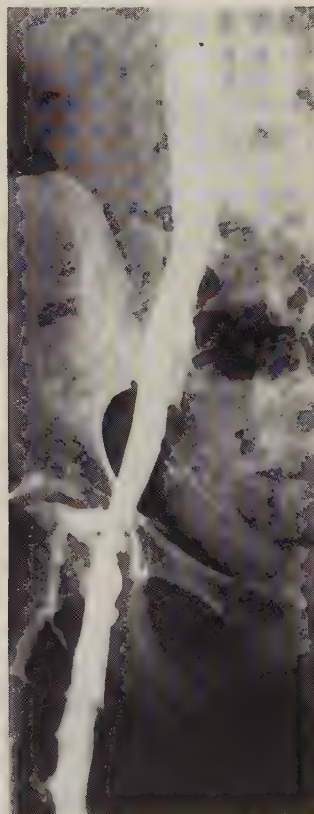


Fig. 5. A. Arteriography with open shunt in patient No. 26 demonstrates a pronounced iliac vein stenosis. B. Phlebography 6 months after shunt closure demonstrates essentially normal vein.

A caval clip had been placed in 3 of the patients, and all of them had a pressure gradient (4 - 7 mm Hg) over the clip. Pressure 20 cm below the shunt level was recorded in 8 patients and was in all of them equal to the shunt level pressure.

Flow measurement. Iliac artery flow without the blood pressure cuff (A) was measured in all 16 patients and was 0.8 - 5.6 l/min (mean 2.2 l/min), whereas cardiac output was 3.5 - 12.8 l/min (mean 6.9 l/min) (Table 2). Iliac artery flow corresponded to 15 - 50 per cent (mean 31 %) of cardiac output and there was a good correlation between this flow and cardiac output (Fig. 2). Flow in patients with normal veins or slight venous stenosis was 1.1 - 4.0 l/min (mean 2.1 l/min) and in patients with moderate to severe venous stenosis 0.8 - 5.6 l/min (mean 2.5 l/min). One patient with a venous occlusion had a flow of 1.4 l/min measured after direct puncture of the femoral vein. In the patients with venous stenosis and a pressure gradient, the flow was between 0.8 and 5.6 l/min (mean 2.8 l/min).

Iliac artery flow was measured at rest without (A) and with (B) a blood pressure cuff, at a pressure of 250 mm Hg, placed high up on the thigh to arrest peripheral circulation in 7 patients. Arteriography was performed in these patients with and without a blood pressure cuff. With the cuff there was no flow in the peripheral arteries except in the circumflex collum femoral arteries. Neither pressure in arteries proximal to the cuff nor vessel diameter changed as distal flow was arrested. The flow at rest was 1.3 - 5.6 l/min (mean 2.6 l/min) and with the cuff 1.3 - 4.9 l/min (mean 2.5 l/min) (Fig. 3). During the hyperaemic phase, after deflating the blood pressure cuff, the measured flow was 1.9 - 5.9 l/min (mean 3.5 l/min).

A small shunt (diameter 3 - 4 mm) was found in 7 patients: 5 had normal veins, one stenosis, and one occlusion. The iliac artery flow in these patients was 1.1 - 2.2 l/min (mean 1.5 l/min) (Fig. 4).

A shunt diameter of 5 - 6 mm was found in 8 patients. Of them, one had normal veins and 7 had a stenosis: the flow in these patients was 0.8 - 4.4 l/min (mean 2.5 l/min). One patient with a shunt diameter of 9 mm and moderate stenosis had a flow of 5.6 l/min.

Chest examination. No change of heart size or pulmonary vessel size was demonstrated in 2 of the patients with a flow of 1.4 and 2.2 l/min, respectively. In another 6 patients, pre-operative chest radiographs were supine ones and inappropriate for a comparison. In the remaining 22 patients, there was cardiac enlargement, which, however, did not exceed the normal limits. A dilatation of the pulmonary vessels as a sign of increased cardiac output was also demonstrated in these patients, but in no patient were there any signs of cardiac decompensation.

Discussion

Arteriovenous shunts have been used in chronic haemodialysis patients for a long period of time, and extensive experimental studies of haemodynamic changes have been performed, although mainly with side-to-side anastomosis /5, 6, 7, 8, 14, 16, 17, 19/. LAVIGNE constructed experimental side-to-side shunts of the loop type - a shunt which is similar to ours - between the femoral artery and vein in dogs with diameters half, equal, double, and 4 times that of the feeding artery /11, 12/. A fistula half the diameter of its feeding artery did not significantly alter cardiac output, proximal arterial flow and pressure, or venous pressure. However, a

significant decrease of distal arterial flow and pressure was found. A shunt equal in diameter to the feeding artery did increase shunt flow and proximal arterial flow fivefold, and significantly increased cardiac output; further, a significant decrease in distal arterial flow and pressure was also recorded. No difference was detected in proximal arterial pressure or proximal and distal venous pressure. Larger shunts augmented these changes, and the largest shunt (four times the diameter of the proximal artery) also caused a reversal of distal arterial flow. With the larger shunts, an increase in distal venous pressure was also found. In our patients, shunt diameter was comparatively small, only 25 - 90 per cent (mean 50 %) of the diameter of the feeding artery.

Studies of shunts with side-to-side anastomosis have given similar results, but reversal of distal arterial flow occurs with a smaller shunt size. These studies were all performed at the time of shunt construction /5, 6, 7, 8, 14, 16, 17/.

Follow-up studies 1 year after construction of proximal shunts showed that there was a continuous increase in shunt flow and proximal and distal arterial flow with time, and also an increase in the arterial diameter /19/. Also distal arterial pressure, which in all early measurements was significantly decreased, normalized later. A steady increase in distal venous flow with time was also found. Such changes with time were not found in a study of peripheral shunts with side-to-side anastomosis in man /5/.

Our own results accord with all of the above findings. The distal arterial pressure when compared with the proximal pressure was equal or slightly decreased in all patients without an arterial stenosis, and we also found an increase in arterial diameter proximal as well as distal to the shunt compared with the normal side /1/. The venous pressure in patients with normal veins was not elevated despite the large increase in flow. Due to the Pitot effect there may be some underestimation of arterial pressure, especially in the iliac artery where flow was high. However, the pressures given in Table 1 are not measured within any stenosis, and we found no pressure difference between the iliac artery, where the catheter tip was directed with the flow, and the aorta where it was directed against the flow. Thus, errors due to the Pitot effect appear to be of minor importance in the artery. On the venous side the flow at the shunt level is very turbulent and the chances of an overestimation of pressure owing to the Pitot effect are minor. Pressures recorded within the venous stenosis, where luminal flow was high, could well be overestimated by the Pitot effect, which could be the reason why we did not find a negative pressure in any patient. None of the pressure values in Table 1 were recorded within a stenosis. Pressure in the iliac veins and vena cava was the same independent of the direction of the catheter tip.

A larger iliac artery flow with increasing shunt diameter was found in most of our patients, as well as in experimental studies /12/. However, the correlation was poor (Fig. 4). This may be due to difficulty in visualizing the shunt in its entirety, since the shunt, as a rule, formed an arch between the femoral artery and vein; hence, it was impossible to exclude a short stenosis.

The method of blood flow calculation in these patients implies that there is an overestimation of shunt flow because the dye to the leg is included in the calculation. In our patients, shunt occlusion by external compression was not possible, which prevented separate measurements of leg flow. To circumvent this, all the vessels distal to the shunt were occluded with a blood pressure cuff at a pressure of 250 mm Hg. Since pressure measurements and arteriography did not reveal any

changes in the proximal vessels compared with examinations without the cuff, the flow values obtained with the blood pressure cuff can be regarded as shunt flow. The only distal vessels open in these patients were the small circumflex collum femoral arteries, and their flow was considered negligible. The correlation between flow measured with and without the blood pressure cuff was good and almost equal, which is reasonable since the normal flow in the leg is 0.2 - 0.3 l/min, which is well within the standard deviations of this method with such high flow rates (Fig. 3). Thus, flow measured without the blood pressure cuff (Flow A) could be regarded as a good approximation of shunt flow.

Cardiac output was adequately increased in all the patients, and there was a good correlation between shunt flow and cardiac output (Fig. 2). As this measurement was not impaired by the same errors as shunt flow measurements, the cardiac output values must be regarded as correct. Cardiac output after subtraction of shunt flow was 2.1 - 7.1 l/min (mean 4.7 l/min), which in all patients but one is within normal limits at rest. If the cardiac output of the latter patient is calculated with subtraction of the overestimation due to leg flow and early appearance of dye, this patient also had a normal cardiac output after "true" shunt flow subtraction. This patient had occlusion of the vein, and both shunt flow and cardiac output measurements are therefore probably unreliable.

The shunt flow reported here seems high compared with experimental measurements in dogs performed immediately after shunt construction. However, an increase in shunt flow up to 50 - 100 per cent during a 1-year period has been described experimentally /19/ and our flow values seem accurate when compared with these measurements. As demonstrated by the measurement during hyperaemia, several patients were able to further increase leg flow and thus were well adapted to the increased flow in the shunt.

Negative pressures have been recorded in proximal veins in experimental shunts and venous collapse due to the Venturi effect has also been demonstrated /4, 8, 9, 10/. Negative pressures were not found in any of our patients; but since the pressure measurement in the vein was performed with the end-hole of the catheter directed against the flow, a negative pressure could be masked by the Pitot effect, which is especially pronounced in the stenotic part of the vein where laminar flow is very high. Most patients had a stenosis with an appearance that is compatible with collapse of the vein caused by the Venturi effect and follow-up examination has, in some patients, demonstrated an increase of the venous diameter after shunt closure, thus speaking in favour of this theory (Fig. 5) /2/. Postoperative fibrosis and scarring should subsequently have made this functional stenosis permanent.

Experimentally and theoretically, it has been shown that a pressure gradient in an artery does not occur until there is a reduction of the arterial cross-sectional area of about 90 per cent in a short circular stenosis /3, 13/. The significance of a stenosis is also depends on the length of the stenosis and upon blood flow. This probably explains why we have found pressure gradients over appreciably less pronounced venous stenoses that, however, had considerable length and where blood flow was high. It is therefore impossible to evaluate the functional importance of a vessel stenosis from arteriograms. These shunts, however, are temporary; and with diminished flow after shunt closure, the stenosis in most patients is probably of little significance /2/.

Our findings accord with experimental studies: the shunt flow depends upon shunt size and, although there is a considerable increase of flow in the femoral vein, venous pressure is not elevated without a concomitant venous stenosis. Distal arterial pressure was normal in our patients 1 - 19 weeks after shunt construction if there was no stenosis. Stenoses seem to be more common in patients with a high shunt flow; this could be due to the Venturi effect or intimal hyperplasia. Perhaps smaller shunts constructed with a branch of the great saphenous vein or more distal shunts would further improve the results by reducing the frequency of stenosis in the iliac veins.

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Femoral Vein Pressure Measurements for Evaluation of Venous Function in Patients with Postthrombotic Iliac Veins

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Abstract. Fifty patients with postthrombotic disease were examined by phlebography and by bilateral femoral vein pressure measurements. The degree of obstruction to venous flow was best evaluated by measuring the pressure elevation and pressure difference after exercise and the time required for these parameters to return to pre-exercise levels; pressures during rest and exercise were less conclusive indicators of obstruction. Good correspondence was found between femoral vein pressure and the severity of postthrombotic symptoms, while phlebography provided largely morphologic, rather than functional, information. We, therefore, consider it important to determine femoral vein pressure during and after exercise to evaluate the significance of postthrombotic iliac vein disease.

Key words: Veins, iliac – Veins, femoral – Venography – Thrombosis, venous.

Following acute venous thrombosis of the leg there may be complete recovery if there is rapid resolution of the thrombus or if thrombectomy is performed immediately. Usually, however, thrombolysis is incomplete, resulting in either persistent occlusion or recanalization with a more or less reduced lumen and incompetent valves. The iliac veins tend to remain occluded because of the development of adequate collateral channels. On the left side, compression from the overlying right common iliac artery may be a factor [7]. The obstruction of the venous outflow from the leg causes venous hypertension with secondary edema and, in cases with poor collateral development, venous claudication.

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Investigation of the venous state in the postthrombotic leg may be made by plethysmography, radioisotope phlebography, and Doppler ultrasound examination, methods that are noninvasive and therefore suitable for screening patients for pelvic vein obstruction [2, 5, 12, 14]. Recording of intraluminal pressure in superficial veins of the foot, and, alternatively, foot-volumetry have also been used to study the postthrombotic syndrome [1, 3, 8, 10, 13]. The results, however, reflect the state of the entire leg and of the pelvic veins. Measurement of the femoral vein pressure may be used to evaluate the contribution of the pelvic vein dysfunction to the postthrombotic syndrome [4, 6].

Femoral vein pressure will rise significantly during exercise in patients with obstruction of the pelvic veins. Evaluation of postthrombotic pelvic veins has been performed by comparing the pressure difference between the legs and the pressure increase during exercise [7, 9, 11].

We have performed phlebography of the iliac veins and the inferior vena cava and have determined the pressure in the femoral veins at rest, during, and after exercise; these findings have been correlated with the severity of postthrombotic symptoms in postthrombotic patients.

Materials and Methods

Femoral vein pressure was measured in 50 patients, 32 men and 18 women, aged between 19 and 76 years (mean, 51 years). All patients had postthrombotic venous disease with a duration of six months to six years.

The examination was performed on a tiltable x-ray table. Both femoral veins were catheterized with end-hole catheters adjusted for free flow. After tilting the table 30 to 45 degrees from the horizontal plane, feet down, phlebography was performed separately on both sides. A second injection was made during Valsalva maneuver to evaluate the femoral valve function.

The intravascular pressure was thereafter measured with a pressure transducer (ENT 34, Elema-Schönander, Sweden) ad-

justed to a reference level 5 cm below the sternum in the supine position. The transducer was calibrated with a vertically adjustable bottle with saline adjusted to 50 cm of water (37 mm Hg).

The pressure was recorded in the supine patient, at rest, during exercise consisting of 20 powerful contractions of the calf muscles (equal on both sides) and immediately after exercise. The recordings were repeated two to three times on both sides, one side at a time, with continuous recording of the pressure on a Minograph (Elema-Schönander).

Central venous pressure was not measured; only pressure elevations and differences between the right and left leg in the individual patients were evaluated. The leg blood flow was assumed to be the same on both sides, and consequently without influence on the pressure. The results were described as the pressure difference between the legs during rest, the pressure and difference during exercise, and the pressure elevation and difference immediately after exercise. When the pressure oscillated, the mean pressure was used. The pressure during exercise was defined as the mean pressure during the last five calf muscle contractions. The time it took for the pressure to return to pre-exercise value after exercise was also measured.

Results

Phlebography

Normal iliac veins on both sides and normal inferior vena cava were demonstrated at phlebography in 17 patients, all of whom had postthrombotic changes in the veins of the calf and thigh. Postthrombotic changes in the pelvic veins on the left side were evident in 21 patients and on the right side in six. Eight of these patients had slight changes, with narrowed lumen and irregular walls, nine had more pronounced changes with recanalization and collateral circulation, and 10 had occlusion of the external and/or common iliac vein. Postthrombotic changes bilaterally and in the caval vein were displayed in six patients, three of whom had occlusion and three recanalization.

Pressure Determination

Normal Iliac Veins. The difference in pressure at rest between the two sides varied between 0 and 2.2 mm Hg. The pressure curve often had fluctuations due to breathing and heart pulsations. These variations were slightly more marked on the right than on the left side, probably due to the cross-over of the right common iliac artery. The curves from the two or three recording sequences were practically identical, except for artefacts such as coughing or muscular movements.

During exercise there was a slight increase in the pressure compared to the pre-exercise level but there was no difference between the two sides. After cessation of exercise, the pressure fell to pre-exercise levels within five seconds (Table 1).

Unilateral Postthrombotic Iliac Veins. In the pressure curves of the postthrombotic iliac vein, pulsations as well as breathing variations were typically less marked or absent. Although there were great individual variations, the pressure difference at rest and exercise in the entire group of 27 patients differed significantly from that in normal patients. There was, however, a less significant difference in pressure elevation during exercise (Table 1). The parameters showing the greatest departures from normal were pressure elevation and pressure difference after exercise, where the mean values were six and eight times higher, respectively, in the postthrombotic patients.

Twelve patients in the group had pressure values and pressure differences that did not differ significantly from those in patients with normal iliac veins. The pressures in these 12 patients returned to pre-exercise levels within 20 seconds, and there was no progressive pressure elevation despite repeat exercise periods.

Table 1. Pressure measurements (mm Hg) in postthrombotic patients with normal and unilateral postthrombotic pelvic veins. (Mean values, SEM, range and significant difference from normal.)

Pelvic vein appearance	No. of pts.	Pressure difference at rest	Pressure rise at exercise		Pressure difference at exercise	Pressure elevation after exercise		Pressure difference after exercise
			Healthy side	Diseased side		Healthy side	Diseased side	
Normal	17	0.8 ± 0.1 (0–2.2)	3.7 ± 0.7 (0.7–9.6)	3.7 ± 0.6 (0–8.1)	2.9 ± 0.9 (0–7.3)	0.4 ± 0.1 (0–1.5)	0.6 ± 0.1 (0–2.2)	0.9 ± 0.1 (0–2.9)
Postthrombotic	27	3.8 ± 0.7** (0–12.5)	2.9 ± 0.6° (0–11)	6.7 ± 0.9* (0–16.2)	7.5 ± 1.3** (0–27.1)	0.3 ± 0.2° (0–3.7)	3.9 ± 0.9** (0–18.4)	7.3 ± 1.5** (0–31)
Normal pressures	12	1.5 ± 0.3* (0–3.7)	2.7 (0–9.6)	2.9 ± 0.8° (0–9.6)	1.7 ± 0.4° (0–3.7)	0.5 (0–3.7)	0.4 ± 0.2° (0–1.5)	1.3 ± 0.3° (0–3.7)
Pathological pressures	15	5.7 ± 1.0*** (0.7–12.5)	3.2 (0–11)	9.8 ± 0.9*** (3.7–16.2)	12.1 ± 1.5*** (3.7–27.1)	0.2 (0–0.7)	6.7 ± 1.2*** (2.2–18.4)	12.1 ± 1.9*** (3.7–31)

Significance level: ° $P > 0.05$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$



Iliac phlebography revealed slight to moderate postthrombotic changes in seven patients and severe changes in three. Two patients had complete occlusion of iliac veins but well-developed collaterals (Figs. 1, 2, and 6).

In the remaining 15 patients, the pressures and pressure differences were significantly elevated compared to normal at rest as well as during and after exercise. The greatest difference from normal was in pressures after exercise, but the individual variations were more pronounced with these parameters. There was, however, only slight overlap in pressure elevation and no overlap in pressure difference between normal and postthrombotic patients (Tables 1 and 2, Fig. 7). The time required for the pressures to return to pre-exercise levels was prolonged in all these patients to more than 40 seconds, and the pressure increased successively with each exercise period. At phlebography the postthrombotic changes were moderate in one patient and severe in six. Eight patients had occlusion of the iliac vein (Figs. 3 and 4).

Postthrombotic Disease of Both Iliac Veins and Inferior Vena Cava. In these six patients, a pressure difference was found neither at rest nor during exercise. After exercise, however, the pressure was significantly elevated in both legs compared with normal patients, and the time required for the pressure to return to pre-exercise levels was more than 30 seconds in all patients (Table 2, Fig. 5).

The clinical evaluation of the patients was in accordance with the pressure measurements. Although

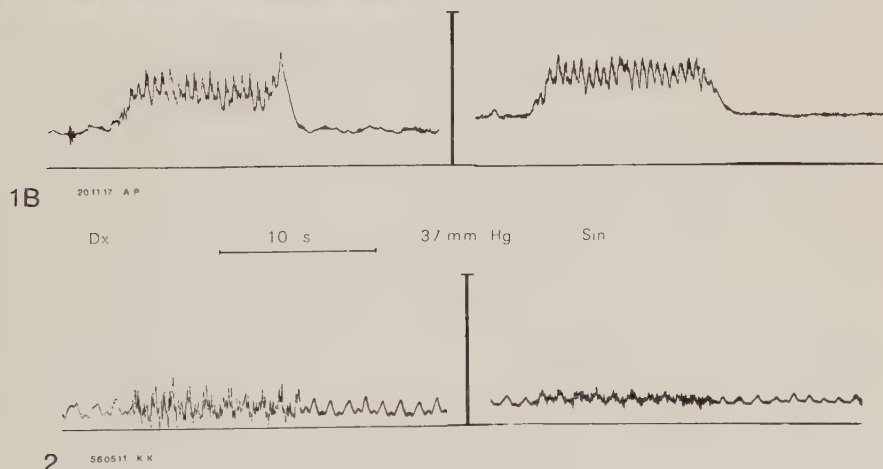
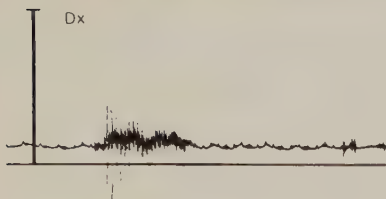
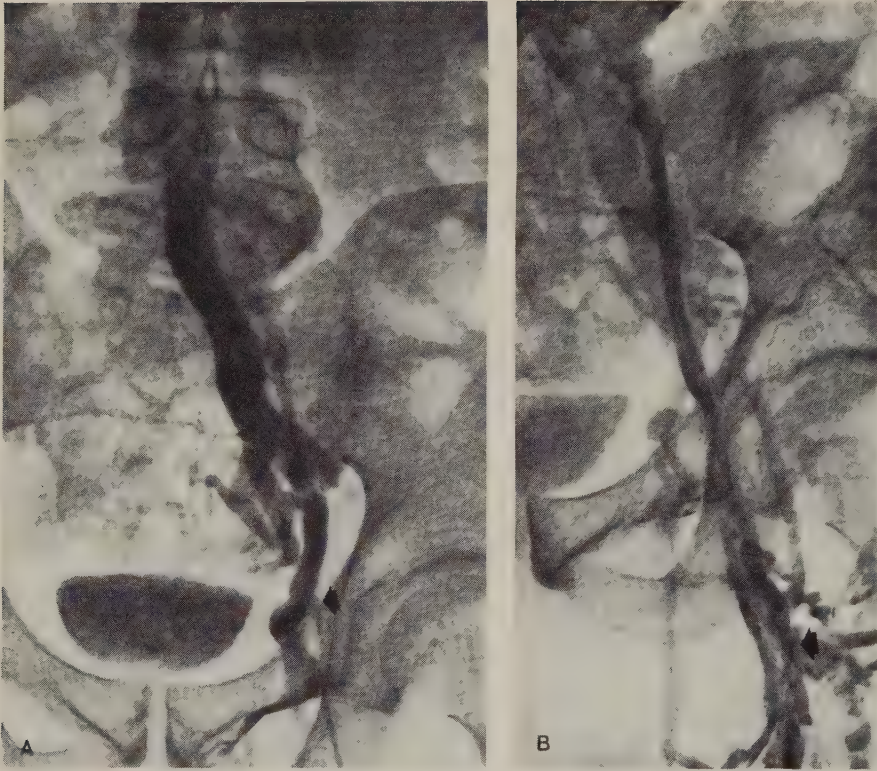
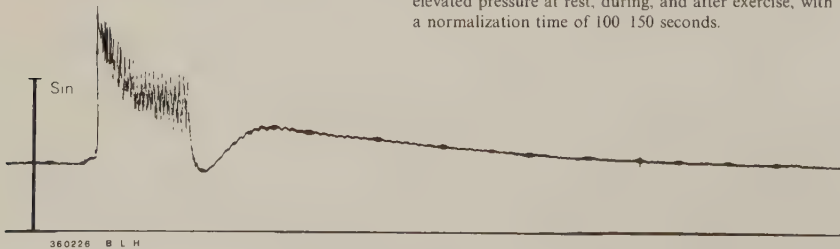


Fig. 1A and B. A Phlebogram of a 58-year-old man with postthrombotic changes in his left leg and pelvic veins. **B** Pressure curves from the same patient showing slight elevation of resting pressure and a more pronounced elevation during exercise on the postthrombotic side with an immediate return to resting pressure after exercise.

Fig. 2. Pressure curve from a 22-year-old man with changes similar to those of the patient in Figure 1. Slight elevation of the pressure on the left, diseased side is shown during rest and exercise. In both patients the pressure is within normal limits.



37 mm Hg 10 s



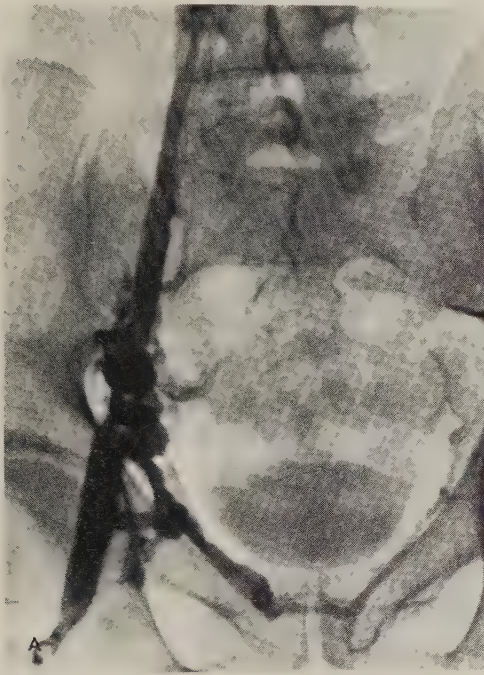
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Fig. 3A–C. A 41-year-old former professional football player with severe postthrombotic changes in the left leg and pelvic veins. Walking distance on tread-mill: 186 meters.

A Phlebography with the catheter in a subcutaneous collateral (*arrow*), the tip above the inguinal ligament. The pressure measurement was normal. Because of the position of the catheter, a new examination was performed.

B Phlebography with the catheter in a postthrombotic common femoral vein (*arrow*) shows severe changes in the femoral vein and external iliac vein.

C Pressure measurement in the latter position reveals elevated pressure at rest, during, and after exercise, with a normalization time of 100–150 seconds.



all patients had postthrombotic disease, only those with signs of venous hypertension with or without signs of venous claudication had significantly increased pressure values and a normalization time of more than 90 seconds.

Discussion

Phlebography provides good morphological information about postthrombotic venous changes as well as about the collateral circulation, but there is often a discrepancy between these findings and the clinical symptoms. Demonstration of postthrombotic changes at phlebography therefore does not necessarily mean that there is a functional obstruction to venous return (Fig. 6). The degree of obstruction is dependent upon the amount of postthrombotic narrowing, length of the occlusion, and the development of collateral veins. The functional importance of local postthrombotic changes can only be assessed by determining the pressure difference over the segment in question. In our study this was demonstrated by two patients with occlusion of iliac veins who had normal pressure determinations, and by seven patients with recanalized vessels without occlusion who had abnormal pressures.

Measurement of the pressure in the femoral vein provides a good assessment of the changes in the

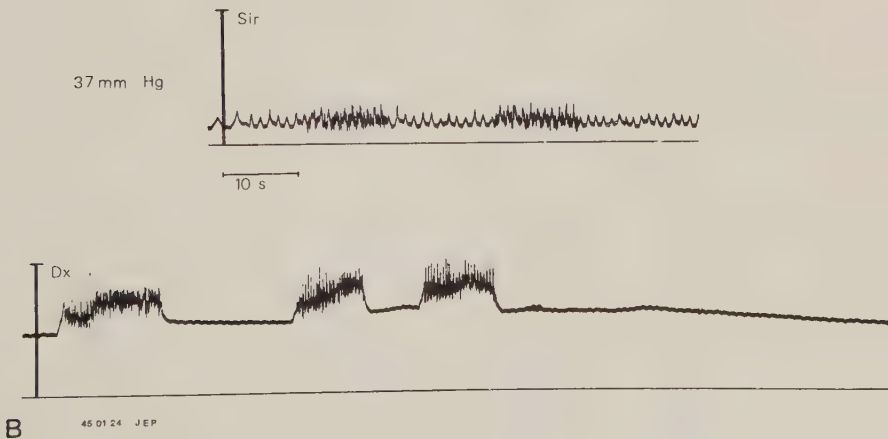


Fig. 4A and B. A 31-year-old man, who developed thrombosis after fracture of his right leg with subsequent slight postthrombotic disease and varicose veins in the groin. After removal of these collaterals, the patient developed venous claudication. **A** Phlebography shows severe postthrombotic changes, mainly in the common iliac vein, with poor collateral development. **B** Pressure measurement: Resting pressure is levelled compared to that of the normal leg. During rest, exercise, and after exercise, pressure is elevated with a long normalization time. Repeated work periods result in a further elevation.

Table 2. Pressure rise at and after exercise (mm Hg) and normalization time (Sec) in all normal veins compared to postthrombotic veins. (Mean values, SEM, range and significant difference from normal)

Pelvic vein appearance	No. of legs	Pressure rise at exercise	Pressure elevation after exercise	Normalization time
Normal	61	3.4 ± 0.4 (0–11)	0.4 ± 0.1 (0–3.7)	0–5
Unilateral postthrombotic				
Normal pressures	12	$2.9 \pm 0.8^{\circ}$ (0–9.6)	$0.4 \pm 0.2^{\circ}$ (0–1.5)	0–20
Pathologic pressures	15	$9.8 \pm 0.9^{***}$ (3.7–16.2)	$6.7 \pm 1.2^{***}$ (2.2–18.4)	40–180
Bilateral postthrombotic	12(2×6)	$4.3 \pm 0.5^{\circ}$ (1.5–8.1)	$4.0 \pm 0.6^{***}$ (0–7.3)	30–120

$^{\circ}P > 0.05$, $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$

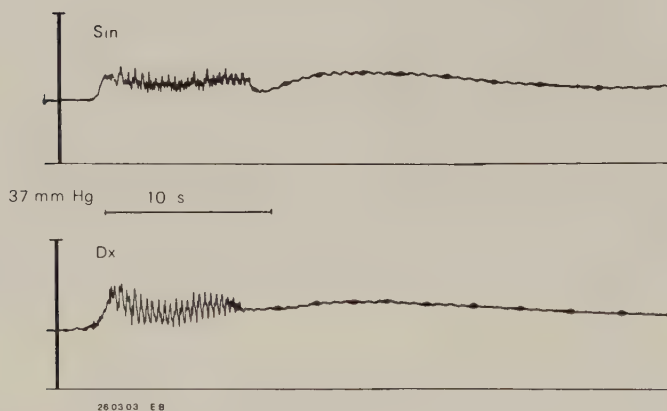


Fig. 5. Pressure curves in a 62-year-old woman with severe postthrombotic disease in her left leg, occlusion of the iliac veins on the left side and common iliac vein on the right side and inferior vena cava occlusion up to the renal veins. There was no difference between sides during rest or exercise and no significant rise of pressure during exercise. Pressure after exercise was elevated on both sides with normalization time of 60 seconds, indicating an obstruction to flow in both legs.

pelvic veins; however, the pressure determination must be made distal to the obstruction if a representative result is to be obtained (Fig. 3). The femoral vein pressure is also influenced by the changes in the calf and thigh veins. During our exercise test, the major increase in blood flow was in the calf muscles; postthrombotic occlusions, stenoses, and valve incompetence in the calf and thigh veins that alter the venous volume, emptying rate, and flow pattern also influence the pressure even if there is considerable potential for collateral development in the thigh.

In our study, patients with postthrombotic changes limited to the iliac veins had a more marked pressure rise during exercise than did patients who

also had occlusion of the femoral vein; this was most pronounced in those with poor collateral circulation. The postthrombotic changes in the femoral vein, however, did not influence the pressure elevation after exercise and the time for normalization of the pressure to the same extent. These two parameters, therefore, seem to correlate better with the severity of the postthrombotic symptoms than does the pressure rise during exercise. The use of them, moreover, makes the evaluation of the significance of bilateral and caval postthrombotic changes possible, since comparison between the sides is unnecessary (Table 2). The evaluation of unilateral disease is also facilitated since comparison with the normal side is less important.



Fig. 6. A 59-year-old woman with occlusion of external and common iliac veins and well-developed subcutaneous and pelvic collaterals. The pressure was not significantly elevated.

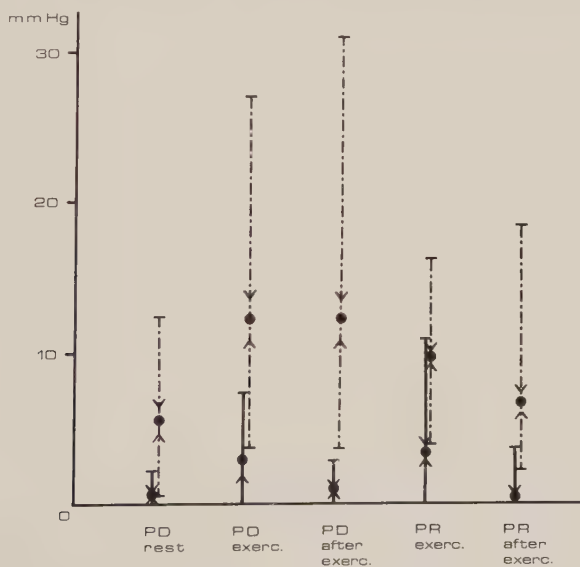


Fig. 7. Pressure difference (PD) and pressure rise (PR) in patients with normal pelvic veins (○) and in those with pathologic pressure measurements (●) at rest, during, and after exercise. (Mean pressure ♦, SEM x, and range [.])

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THROMBECTOMY AND TEMPORARY ARTERIOVENOUS
SHUNT IN ACUTE DEEP ILEOFEMORAL THROMBOSIS:
LATE PHLEBOGRAPHIC EVALUATION OF ILIAC AND
COMMON FEMORAL VEINS

ULF ALBRECHTSSON, EIBERT EINARSSON, BO EKLÖF and ULF TYLÉN

Abstract

A thrombectomy was performed and a temporary arteriovenous shunt constructed in 70 patients with deep ileofemoral venous thrombosis; further phlebography was done as a late follow-up examination in 52 of these patients. Femoral vein pressures were measured bilaterally in 27 patients. Normal phlebography or pressure measurements were found in 31 (60 %) of the 52 patients. This implies that thrombectomy and a temporary arteriovenous shunt are satisfactory as routine treatment for deep ileofemoral venous thrombosis. We expect improved results in the future as we have gained experience from these first patients.

Key words

Ileofemoral thrombosis - Thrombectomy and arteriovenous shunt - Phlebography - Post-thrombotic disease

Acute deep ileofemoral venous thrombosis is a great danger to the patients. Even with anticoagulant therapy, lethal pulmonary embolism occurs in up to 11 per cent of the patients with acute ileofemoral thrombosis. Thrombolytic treatment is theoretically effective, as it activates the fibrinolytic systems. However, it is contraindicated in many patients and is probably not as effective as previously thought /2, 6, 23/. Furthermore, rupture of the liver and spleen has occurred and we therefore have abandoned this method /10/.

Thrombectomy for deep venous thrombosis became extensively used during the 1960s after encouraging reports /13, 22/. The introduction of Fogarty's balloon catheter then made the technique better and easier /11/. Summaries of some of the published reports on about 900 patients have been published /5, 12/, and the overall clinical results after thrombectomy were considered excellent or good in about 80 per cent. Recurrent thrombosis, however, was found to be very common and the clinical improvement did not correspond to the phlebographic findings at follow-up /17/. The very poor long-term results after thrombectomy is stressed in a follow-up study /19/.

In an effort to improve our treatment of deep ileofemoral venous thrombosis, we have used thrombectomy combined with a temporary arteriovenous shunt in 70 patients /3/. In this report we want to present and discuss the follow-up evaluation of the iliac segment with phlebography and intravenous femoral pressure measurements.

Thrombectomy and a temporary arteriovenous shunt were performed in 70 patients /3/. Indications for an operation was an acute venous thrombosis of the ileofemoral segment in all of these patients. Thrombosis of the inferior vena cava was found in 5 patients, and in another 14 the thrombus plug was protruding into the inferior vena cava. The clinically estimated age of pelvic vein thrombosis at the time of operation was 1 - 11 days, (mean 3 days). Thrombectomy was performed with a Fogarty's balloon catheter proximally and distally from an incision in the common femoral vein. The great saphenous vein, or in a few patients one of its branches, was after division anastomosed end-to-side to the superficial femoral artery, thus creating an arteriovenous shunt.

Phlebography was performed in 52 (53 operated legs) of the 70 operated patients: 30 males and 22 females, aged 14 to 72 years (mean 52 years) (Fig. 1). Fifty-one of them were previously examined with arteriography for evaluation of early thrombectomy results 1 - 19 weeks (mean 8 weeks) after shunt formation /3/. Eighteen patients were lost to follow-up because of contrast medium allergy, unrelated disease, or death.

Bilateral femoral vein phlebography and pressure measurements were performed in 27 (28 post-thrombotic legs) patients during rest and exercise. Only phlebography on the operated side was performed in the remaining 25 patients, as pressure measurements were deemed to be unnecessary because of normal phlebography or because femoral vein catheterization was not possible. The phlebography was performed 1 - 59 months (mean 15 months) after thrombectomy; only 2 patients were examined after less than 6 months. Forty-four of the patients examined had their shunts closed at the second operation 6 - 26 weeks (mean 12 weeks) after surgical construction; in the other 8 patients, the shunt had occluded spontaneously.

Ascending phlebography of the leg was performed as described by GREITZ modified according to RABINOV and PAULIN. In patients with patent veins in the groin, one of these was catheterized when possible to demonstrate the iliac veins better and for pressure measurements. Frontal, and in some patients, oblique projections were taken with the patient semierect after injection of 30 ml of contrast medium. Radiographs were taken also during a Valsalva manoeuvre to evaluate the degree of insufficiency of the thigh vein. Femoral vein pressure measurements were performed bilaterally in 27 patients during rest and exercise to evaluate the functional significance of phlebographic changes. The pressure was recorded in the supine patient at rest, during exercise (consisting of 20 powerful contractions of the calf muscles), and immediately after exercise. The recordings were repeated 2 - 3 times on both sides, one side at a time, with continuous recording of the pressure on a Polygraph. Because central venous pressure was not measured, only pressure elevations and differences between the right and the left leg in the individual patients were evaluated. In an earlier study /2/ we found that normal and pathologic venous function was best discriminated by the pressure pattern after exercise rather than during exercise. Therefore, in this study the pressure measurements were considered as pathologic when there was an elevated pressure after exercise of more than 5 mm Hg or the difference between the two legs was more than 4 mm Hg. Time for normalization of the pressure after cessation of exercise should exceed 30 seconds.

Iliac vein changes were described as cross-sectional area reduction estimated from the decrease of luminal diameter and were classified as normal, slight stenosis (< 75 %), moderate stenosis (75 - 90 %), severe stenosis (> 90 %), and occlusion. Comparisons between phlebography, pressure measurements, and previously performed arteriography were made (Table 1).

Results

Phlebography. Post-thrombotic changes in calf and thigh veins were demonstrated in all the patients except 5, in whom the thrombosis involved only pelvic veins.

Normal iliac veins were demonstrated in 20 legs, whereas in 12 there was stenosis and in 21 occlusion. At the previous arteriography, normal iliac veins were demonstrated only in 13 of the phlebographically normal legs; 6 had a stenosis of varying degree and one was not examined.

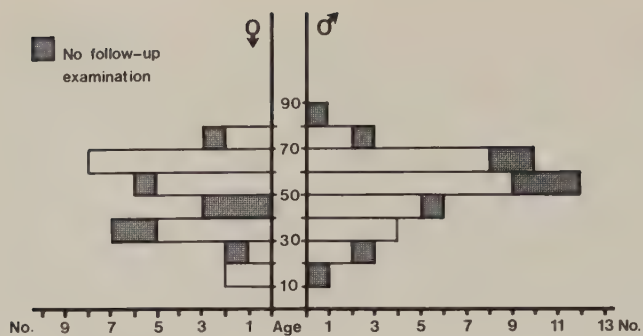


Fig. 1. Age and sex distribution of the operated 70 patients.

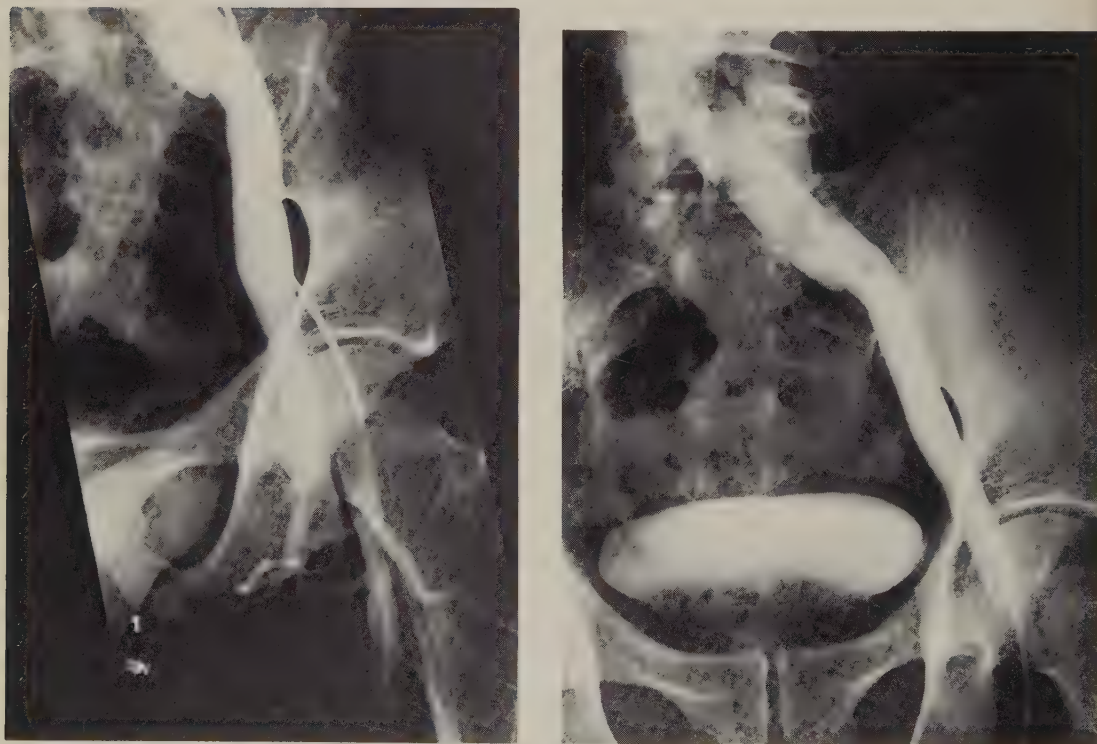


Fig. 2. A. Arteriography demonstrates a well-functioning shunt and a slight stenosis in the common femoral vein. B. Follow-up phlebography: normal findings.

Table 1. Iliac vein appearance at phlebography (53 legs) compared with femoral vein pressure measurements and arteriography

Arteriography	No. of legs	P h l e b o g r a p h y				Occlusion
		Normal	Slight stenosis	Moderate stenosis	Severe stenosis	
Normal	18	13	-	2	-	3
Slight stenosis	6	3	-	1	-	2
Moderate stenosis	8	2	1	4	-	1
Severe stenosis	7	1	1	2	-	3
Occlusion	5	-	-	-	-	5
Not demonstrated	9	1	-	-	1	7
TOTAL	53	20	2	9	1	21
Femoral vein pressure						
Legs examined	28	13	1	8	1	5
Normal pressure	23	13	1	7	1	1

Of the 6 patients with venous stenosis at arteriography, phlebography now demonstrated that 3 had an actual increase of venous diameter between the examinations and the veins were now normal. One of these had a severe stenosis at arteriography (Figs. 2, 4, and 5). In the other 3 patients, the estimated degree of stenosis was reduced because of reduction in diameter in the parts of the vein surrounding the stenosis (relative stenosis)(Fig. 3).

Of the 12 patients with stenosis at phlebography, the degree of stenosis compared with arteriography was unchanged in 4 patients, had increased in 3, and was decreased in 4. In 2 of the latter 4 patients, there was an actual increase in the minimum venous diameter between the 2 examinations. One patient had an occluded shunt at arteriography.

Occlusion of iliac veins was demonstrated at phlebography in 21 of our patients (40 %). Five of them had iliac vein occlusion at arteriographic follow-up and 3 severe stenosis. Occlusion of the iliac veins after shunt closure also occurred in 3 patients with normal veins and in 3 with slight to moderate stenosis at arteriography. In 7 patients the iliac veins were not demonstrated at arteriography because of shunt occlusion. Compared with arteriography, there were, accordingly, an additional 9 occlusions in previously open veins, in 3, however, as a result of a new pelvic vein thrombosis. All occlusions except those caused by a second pelvic vein thrombosis were in the segment of the vein involved by the initial thrombosis. The occlusion in 5 of the patients was short and on the left side and involved only the segment of the veins where it was crossed by the right common iliac artery. In at least one patient the occlusion was secondary to an inadequately performed thrombectomy.

One patient contracted her thrombosis during the third month of pregnancy, and the initial examination was performed only to verify the diagnosis of iliac vein thrombosis and did not demonstrate its whole extension, nor was any follow-up arteriography performed in this patient. Phlebography after termination of pregnancy showed occlusion of the inferior vena cava and both iliac veins; we do not know whether her changes were due to a recurrent thrombosis or an inadequate thrombectomy.

We found no relationship between iliac vein patency and shunt patency time, follow-up time with phlebography, or with age of iliac thrombosis at operation. There is, however, a tendency for somewhat higher patency in those patients with a shunt diameter of 4 mm or less (Fig. 6). Similar results were found at arteriography, as well as at follow-up phlebography.

Pressure measurements. Bilateral femoral pressure was measured in 27 patients (28 operated legs) to evaluate iliac vein function (Table 1). The 13 phlebographically normal legs also had normal pressures, as well as did the only patient with a slight stenosis who was examined. Moderate stenosis was found in 9 patients; 8 of them were examined and 7 had normal femoral vein pressures. Also, the only patient with severe stenosis had normal pressures, whereas only one leg of 5 examined with occlusion of the iliac vein had a normal pressure measurement. This one patient had a short occlusion of the common iliac vein. Of the remaining 24 patients whose pressures were not measured, 8 had a normal phlebography, and in the remaining 16 patients femoral vein changes precluded catheterization.

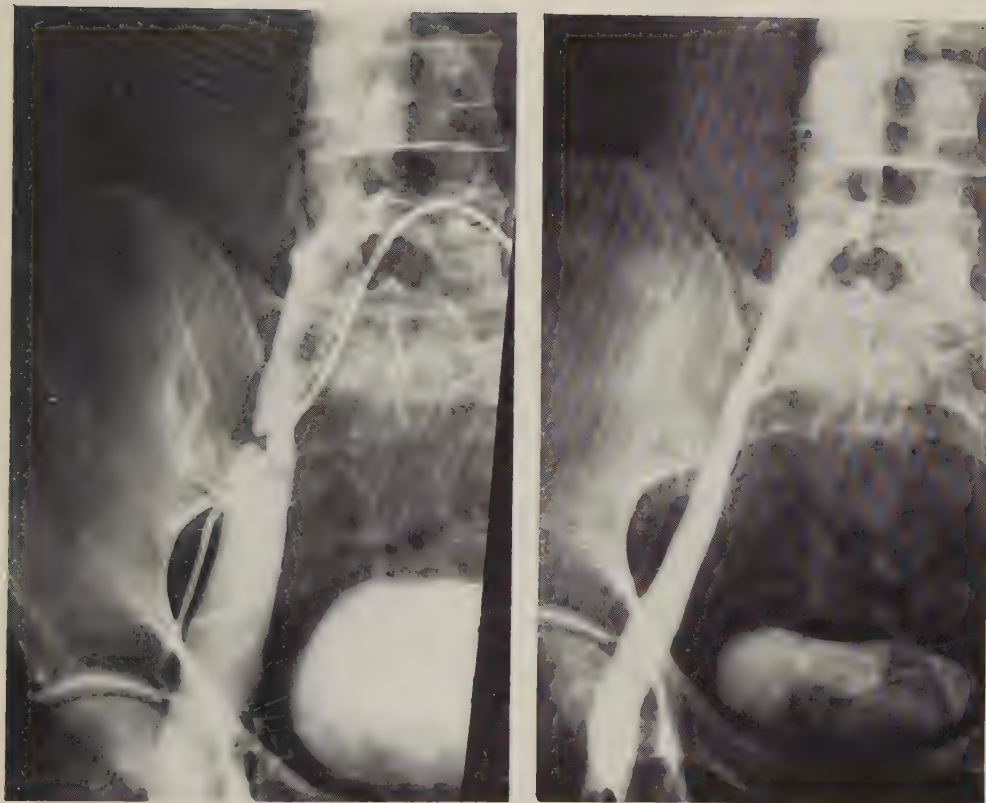


Fig. 3. A. arteriography: well-functioning shunt with an irregular stenosis in the common iliac vein. B. Follow-up phlebography demonstrates a narrow common iliac vein with no change in diameter compared with A, but the degree of stenosis is reduced.

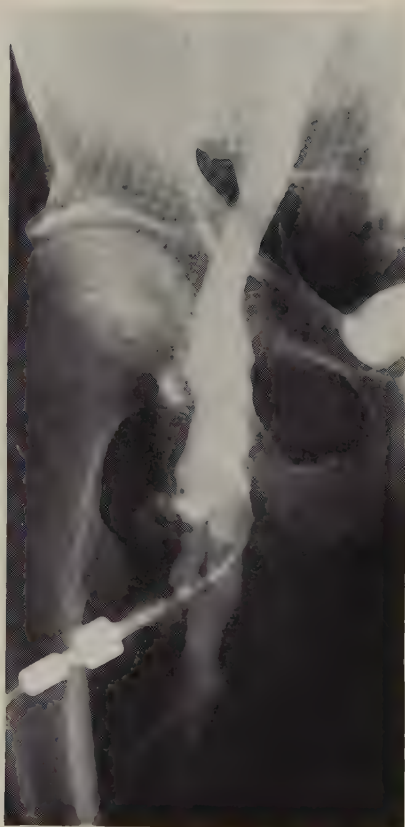


Fig. 4. A. Arteriography: well-functioning shunt with severe femoral vein stenosis. B. Follow-up phlebography. Normal femoral vein.



Fig. 5. A. Arteriography: functioning shunt and moderate venous stenosis just above the orifice of the shunt (arrow). B. Follow-up phlebography: contrast injection during Valsalva manoeuvre demonstrates a normal common femoral vein.

Patient

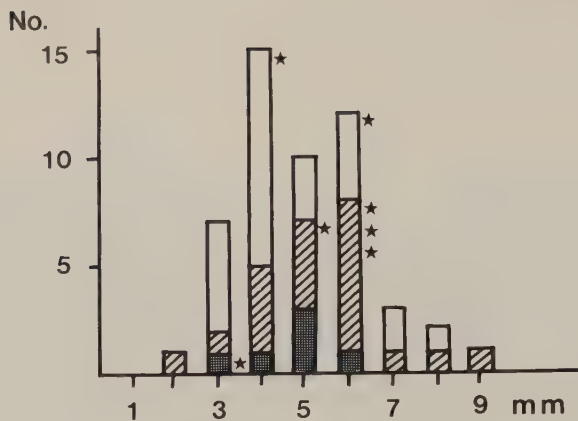
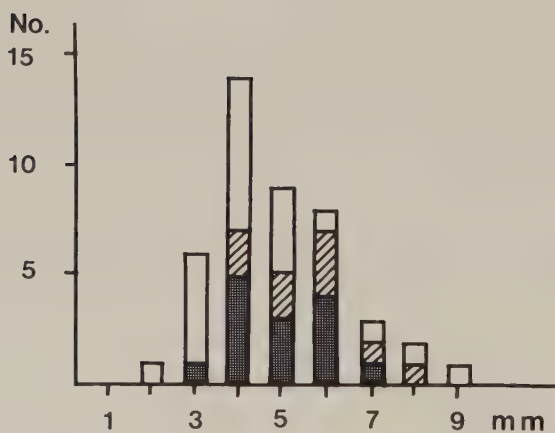


Fig. 6. Results at A. (top) arteriography, and B. (bottom) phlebography correlated with shunt diameter. Successful results were more frequent in those patients with smaller shunts. (★ Patients not examined with follow-up phlebography)

□ normal
 ▨ stenosis
 ▩ occlusion

Patient



In summary, phlebography demonstrated 32 patent iliac veins (60 %), although 12 (23 %) had some degree of stenosis. Pressure measurements were performed in 28 post-thrombotic legs, and were normal in 23 (82 %) despite an occlusion in one case and stenotic changes in 8. All the patients with a normal phlebography had normal venous pressure. Provided that the venous pressure was normal in 8 unmeasured patients with phlebographically normal iliac veins, normal venous function could be found in 31 of the 52 patients (60 %).

Discussion

Most authors have used clinical criteria to evaluate the results after thrombectomy that are inadequate for determining the state of operated iliac veins. A good clinical result is often found even when there is an occlusion of the veins /17/. On the contrary, changes in the phlebogram do not necessarily correlate with poor venous function /2/. Early follow-up studies after thrombectomy are often optimistic, but later follow-up series reveal the high risk for recurrent thrombosis /5, 12, 19/.

The purpose for surgical construction of an arteriovenous shunt is to maintain patency of the thrombectomized venous segment and in cases of persistent occlusion or stenosis to induce development of sufficient collateral veins. Experimental studies have shown an increased patency rate of venous grafts after construction of arteriovenous shunts distal to the graft /14, 29/. Experimental studies and clinical experience have demonstrated that the arteriovenous shunts result in high flow rates in the veins proximal to the shunt and that venous pressure is not elevated more than a few mm of Hg in non-stenotic veins /4, 7, 8, 14, 16, 20, 21/.

There are few reports on patients who have undergone a thrombectomy and temporary arteriovenous shunt construction after acute ileofemoral thrombosis. BAUMANN reported 40 thrombectomized patients in 20 of whom a temporary arteriovenous shunt was constructed /5/. The results were somewhat better with a shunt. VAN DE BERG found a significantly better result in 15 patients who underwent thrombectomy and temporary arteriovenous shunt construction compared with conventional thrombectomy /27/. Further, VOLLMAR and HUTSCHENREITER reported 55 patients who had a thrombectomy and a temporary arteriovenous shunt: good clinical results were found in 83 per cent of these patients, whereas good results were found in only 60 per cent of patients who underwent only a thrombectomy /28/. On the other hand, one report of treatment of experimental thrombosis by thrombectomy, with and without a temporary arteriovenous shunt, showed no significant difference between the two groups /26/.

In our material iliac vein occlusion was demonstrated in 21 patients (40 %). Seven of these patients had not been examined arteriographically and another 5 already had an occlusion at the arteriographic follow-up examination. Of the remaining 9 patients, 3 had a new pelvic vein thrombosis, whereas in 6 the vein occluded after shunt closure. In all of these patients the occlusion was in a segment of the vein that was involved by the initial thrombosis, and in 2 patients only a short segment of the vein was occluded where it was crossed by the common iliac artery. Operative manipulations at shunt closure could, of course, induce a venous occlusion, but the occluded part of the vein was in most patients well away from the operative site. A recurrent thrombosis would

probably have involved larger segments of the veins as in the 2 patients where this was known to have happened. Anatomical changes such as a fibrotic venous spur /24/ could give rise to an occlusion after reduction of blood flow at shunt closure, but no such anatomical changes were demonstrated at arteriography.

Microscopic examination of stenosed veins in shunts used for chronic haemodialysis has shown reactive hyperplasia and fibrosis related to arterial pressure effects /14/. These changes were interpreted as the cause of the stenosis. However, pressures in non-stenosed veins central to an arteriovenous shunt were normal and the microscopic changes must be secondary to the elevated pressure at a stenosis /4, 7, 8, 14, 16, 20, 21/. Another possibility is that the stenosis develops because of a repeated trauma from high turbulent flow from the shunt /9/.

In our series, 7 patients had severe stenosis at arteriography, which, of course, could occlude (3 did) when the blood flow was reduced after shunt closure. The remaining 4 patients, however, had a decrease in the degree of stenosis at phlebography: 2 of them actually had an increase in venous diameter (Figs. 4 and 5). Similar results were found in the patient with a slight stenosis. These findings do not agree with the theory of fibrotic stenosis, but could be explained by spasm secondary to irritation from the shunt flow or by a collapse of the vein wall because of the Venturi effect secondary to the high velocity of the shunt blood streaming into the common femoral and iliac veins. In several experimental studies, negative pressures have been recorded in the vein just central to an arteriovenous shunt, and venous collapse at this site has also been demonstrated /7, 16, 18/. In 21 of the 26 patients with a stenosis at arteriography, the appearance of the stenosis accorded with the Venturi effect, i.e. a long sand-glass-shaped narrowing. Because of oedema and tenderness at the operation site, external shunt closure by compression to demonstrate reversibility of the stenosis was impossible during arteriography, and hence the Venturi effect could not be dismissed. All stenoses of this type were immediately central to the shunt or just above the inguinal ligament, where the vein normally is somewhat narrowed and such stenoses were somewhat more common in patients with large shunts (Fig. 6) /3/. This type of collapse could result in a permanent stenosis due to fibrous post-operative scarring in the soft tissues surrounding the vessels or in the vein. In some patients with less pronounced post-operative changes, it is possible for the vein to regain its normal diameter after shunt closure, as has been demonstrated in some of our patients.

One explanation for the occlusions could be that several patients at operation had wall-adherent thrombi, which were impossible to remove in spite of a short duration of symptoms of iliac thrombosis. In at least one patient the ascending lumbar vein was catheterized instead of the common iliac vein during thrombectomy. The 5-cm-long aneurysm probably created when the balloon was inflated was occluded at the follow-up phlebography and the ascending lumbar veins served as the main collaterals.

The follow-up results were independent of shunt patency time or the time between thrombectomy and phlebography. The 2 patients examined less than 6 months after thrombectomy both had occluded shunts at arteriography and at phlebography one occluded and one normal vein. The optimal time for shunt closure is not established yet. The question is when the vein is re-endothelialized after thrombectomy. We have an experimental study in dogs in progress to evaluate this, and preliminarily a shunt patency time of at least 3 - 4 weeks is necessary. Experimental studies have shown that a temporary arteriovenous shunt for 3 weeks is adequate time to secure patency of venous grafts, but this period was perhaps not sufficient in this

group of patients who often had severely damaged veins /7/. In this series the minimum shunt patency time was 6 weeks.

It is well known that an occlusion of iliac veins can occur without affecting venous function. Phlebography provides a good morphological description; but to evaluate function, pressure measurements are necessary. This combined examination procedure in 28 legs demonstrated normal function in 7 patients with moderate stenosis, one with severe stenosis, and in one of 5 examined patients with an occlusion. Because the main objective is to restore function, the results in these patients must be considered as successful even if phlebography is not normal. Consequently, the combination of phlebography and pressure measurements showed in the examined patients good results in 31 of the 53 legs (60 %), in this late follow-up study. These results compare well with the results of other treatment methods and can probably be improved.

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